COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

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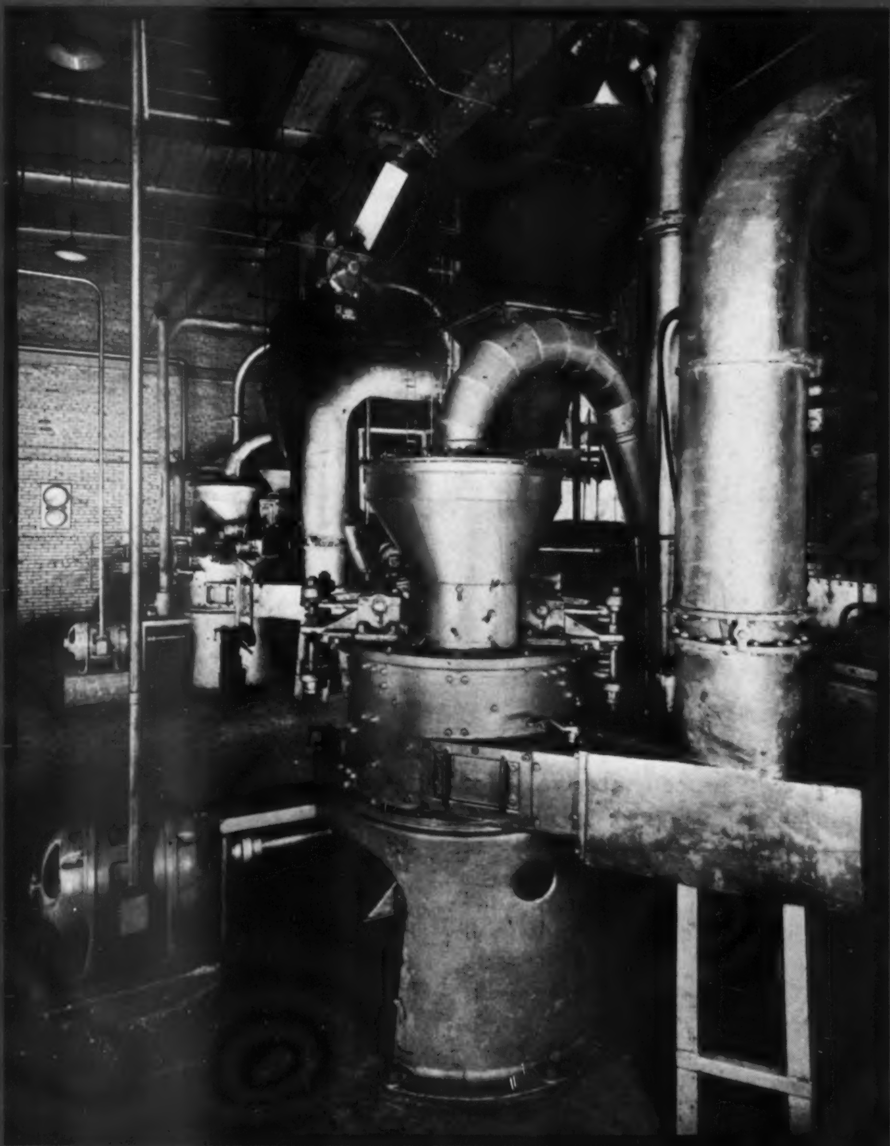

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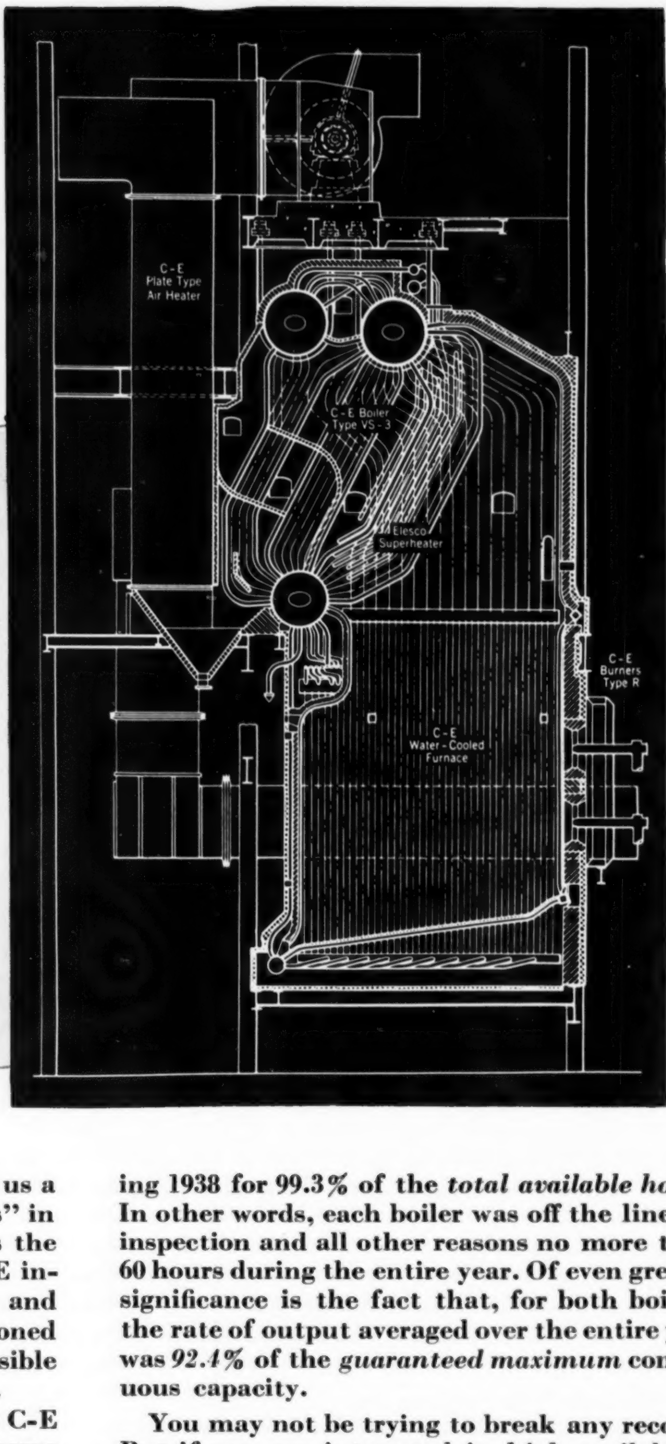

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME ELEVEN NUMBER THREE

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EDITORIAL

Increase in Power Demand

The curve of monthly output of electricity based on data compiled by the Edison Electric Institute, while following very closely the normal seasonal trend, has thus far averaged nearly twelve per cent higher than that of last year. Except for one month this spring, it has been above that of 1937 and during the latter part of August reached an all-time high, despite the fact that industrial production was considerably below that of 1937. A marked increase is shown in the output of fuel-burning plants.

New capacity added or contracted for during the last two years appears to be in line with the present demand, but should Congress repeal the present neutrality law and thus lift the embargo on the export of war materials to Europe it is anticipated that this would be reflected in further sharp increases in power demand which in some cases would probably necessitate additional capacity. Recalling the experiences of 1914 to 1917, this would likely affect the delivery of certain materials and perhaps their price structure. Thus far, there have been no tangible indications of such a situation but much depends upon what transpires in the next few months, or perhaps weeks.

Power Supply Protection

For months past the European technical press, particularly the British, has devoted considerable space to air-raid protection. That it was justified in doing so is borne out by subsequent events. Much of this discussion has dealt with the protection of power plants which are considered military objectives in view of the dependency of industry upon adequate power supply for the production of war material.

Many types of building construction and arrangements of power plant equipment have been proposed to lessen and localize the damage and extent of outage in the event of a direct hit. Included has been the suggestion that stacks be omitted as these serve as landmarks from the sky. Some of the proposals have been fantastic whereas others appeared to have merit. While they have served as the basis for interesting and perhaps useful discussion, the rapidity of events has precluded putting many of the suggestions into effect. It is reported upon good authority that several underground power plants have been installed on the Continent, some in countries adjacent to the present belligerents; but such plants are of relatively small capacity. A number of small portable power plants have also been built as emergency measures, and cooling towers, which are used extensively in England, have been camouflaged.

The practice for some time in Germany, under governmental direction, appears to have been toward decentralization of power supply, as applied both to utilities and private manufacturing plants; the sacrifice in operating economy and first cost being weighed against military considerations. This was quite apparent in conversations with German engineers who attended the World Power Conference in this country in 1936.

In England, on the other hand, the trend during the past few years has followed that of the United States in the adoption of large units, the concentration of power in large economical power stations, interconnection of these, and the retirement of smaller, less economical stations. Whether such practice is a military liability future events will prove. The success of defending such stations from air attack may exert some influence on future practice in this country.

Meeting Programs

The fall and winter seasons of engineering society meetings are approaching, although program committees and authors have been busy during the summer. The educational value of such meetings for recording progress in the various fields and the opportunities offered for the exchange of ideas and experiences through discussion are unquestionable, but there is a well-founded belief among many engineers that programs too often stress quantity rather than quality.

Instead of progress and activities in the respective fields serving as a guide, program committees are prone to set up a certain number of sessions or papers as a bogie and then scout about to secure topics and authors to fill the programs, with too little regard as to whether all may be warranted. This often results in some mediocre papers that are a rehash of well-known facts and trends, and crowded programs involving simultaneous sessions, or too many papers to a session, with the result that profitable discussion is limited and those in attendance are compelled to choose between two or more sessions that command their interest. Obviously, where a society embraces a very broad field some multiple sessions at a general meeting are unavoidable, although divisional meetings have proved a partial solution to the problem.

The responsibility does not rest solely with program committees; extensive society organization and a desire to serve the interests of a large and diversified membership are also factors.

Where a paper is outstanding and represents a distinct contribution to engineering knowledge on a particular subject, its presentation before different regional groups would seem warranted. This practice has been followed to some extent abroad, thus affording a larger audience and the benefits of wider discussion.

These comments are not to be taken as applying alone to any one society or association nor to any particular program, for the tentative programs of several reveal the same trend.

Recirculation of Boiler Water to Hot-Process Softeners

By JOHN J. MAGUIRE* and W. J. TOMLINSON†

In the June 1939 issue of COMBUSTION S. M. Sperry discussed the recirculation of from 1 to 2 per cent of the boiler water to correct the hydrogen ion concentration of the feedwater for the protection of economizers, feed pumps and feed piping. The present authors discuss several additional ways in which advantage can be secured by boiler water recirculation. The most obvious method is return of boiler water to hot-process softeners, either of the lime-soda or phosphate type. However, under certain conditions, it can be employed with cold-process softening, either batch or continuous. Among other uses considered are return to coagulation tanks for alkalinity adjustment prior to filtration and the substitution of recirculated boiler water for soda ash used in conjunction with alum in condensate oil removal systems. Necessary blowdown equipment, control and most suitable tie-in to the system will vary in different cases and, therefore, each must be calculated on the basis of operating conditions and equipment available. Generalities are difficult to apply and each individual application of recirculation must be based on the particular conditions encountered.

RECIRCULATION of boiler blowdown water either to the suction side of a boiler feed pump or to a hot-process softener is receiving steadily increasing attention. The advantages and economies that can be effected by such recirculation have proved so outstanding in many instances that plant operators have become greatly interested in whether or not such advantages and economies cannot be secured under their own particular conditions. Recirculation of boiler water is not universally applicable but one of the greatest fields for the application of recirculation is in such cases where hot-process softeners either of the lime-soda or phosphate type are employed.

The recirculation of boiler water for the protection of economizers, boiler feed lines and boiler feed pumps has recently been described in considerable detail and the experiences of various plants using this system have been presented. Under normal conditions the recirculation of from 1 to 2 per cent of the boiler water will so increase the pH value of the feedwater as to afford satisfactory inhibition of corrosion. Where recirculation of boiler water to a hot-process softener is practiced it is usual to recirculate a considerably greater quantity of boiler water amounting, in many cases, to as much as 10 per cent of the total water fed to the boiler.

Reclaiming the heat contained in the boiler water blowdown is not necessarily the prime object of recirculation. It can be applied to advantage in many instances where the recirculated boiler water has first given up its heat to the incoming makeup water, having passed through a heat exchanger. In some cases the continuous blowdown from the boilers will pass to a flash tank and the concentrated water from the flash tank be led through a heat exchanger to almost totally reclaim its heat. Recirculation of this concentrated and cooled boiler water blowdown has definitely been of considerable advantage.

The reduction that is secured in chemical treatment to the softener by reclaiming the sodium carbonate and sodium hydroxide present in the boiler blowdown is also in many instances a minor point. Recovery of the sodium carbonate and sodium hydroxide of the boiler water blowdown has often been stressed as a primary reason for adoption of recirculation and has as often been criticised for the relatively small advantage gained therefrom. The application of recirculation to any given set of plant conditions requires careful study not only of the type of makeup water employed but also of plant equipment and the general heat cycle.

Boiler Blowdown

With external lime-and-soda softening, particularly with a relatively low percentage of returned condensate, it is often difficult to prevent high boiler water alkalinities with their consequent tendency for entrainment of solids with the steam. Of course, these high boiler water alkalinities can be corrected by a high rate of blowdown but this is objectionable because of three factors, namely, cost of additional raw water necessitated by increased blowdown, cost of treating that additional raw water and the loss of heat resulting in greater fuel cost. However, by recirculating the increase in blowdown back to the softener any increase in raw water is avoided. Secondly, the recirculated boiler water is already treated and, in fact, contains overtreatment in the form of excess alkalinity which is available for reducing the lime and soda ash necessary for softening the remainder of the makeup water. In the third place, the heat contained in the boiler water blowdown is

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returned to the system, thus preventing loss in economy from this factor.

Reduction in blowdown by means of recirculation can only be secured where alkalinity of the boiler water is the limiting factor in governing the rate of blowdown. This is usually the case where a lime-soda or external phosphate softener is employed. No reduction in the rate of blowdown can be achieved by recirculation where the sulfate or chloride concentration of the boiler water is the limiting factor in the regulation of blowdown. This point can be readily visualized when it is realized that reduction in blowdown is effected by using the high alkalinity of the boiler water in the softener in place of lime and soda ash. The alkalinity in the recirculated boiler water is removed from solution as it effects the precipitation of the hardness contained in the raw water.

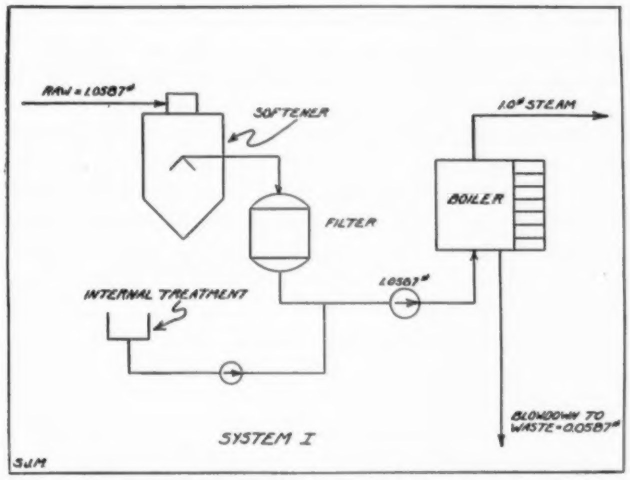

Fig. 1—Steam and water balance of plant employing hot-process lime and soda for external treatment of a high bicarbonate water

No such removal of sulfate or chloride from the system is obtained, however, and when either sulfate or chloride is present in large concentrations, recirculation of blowdown is normally not practical. However, an increase in the sulfate and chloride concentrations can normally be tolerated better than an increase in alkalinity. Since the boiler operates under a reduced number of cycles of concentration, compared to the boiler feedwater, it is possible to maintain higher softener alkalinities without correspondingly high boiler alkalinities. Excess treatment in the softener by recirculation can be particularly advantageous where high organic content of the water makes difficult the establishment of a suitably low hardness without use of a large excess of lime and soda ash and consequent high boiler-water alkalinities. An ideal application for the recirculation of boiler water is in such cases where sodium sulfate is added to the boiler water to increase the sulfate-carbonate ratio. Since recirculation will increase the concentration of the sulfate naturally present in the water without increasing total boiler-water alkalinity, then the only factor that will increase under such conditions is the chloride content of the boiler water.

The system illustrated in Fig. 1 shows the steam and water balance of a plant employing a hot-process lime-and-soda softener for external treatment of a high bicarbonate water. Table I illustrates the analysis of the raw water, boiler feedwater and boiler water. While based upon an actual set of conditions, these illustrations have been somewhat simplified for ease of explanation. No returned condensate is received and the condensation of exhaust steam in the softener has been neglected, assuming 100 per cent makeup water. The 20 ppm hardness present in the boiler feedwater has been assumed to precipitate in the boiler totally as calcium carbonate, and sodium sulfate is fed as part of the internal treatment in order to maintain a sulfate-carbonate ratio of 1.0. It had been found that the maximum safe limit of boiler water alkalinity that could be maintained without carryover was 755 ppm. Since 100 per cent makeup was in use the cycles of concentration of the boiler based on feedwater and based on raw water were identical, as were the percentages of blowdown of the boiler and of the entire system.

TABLE I

			Raw	Feedwater	Boiler
ppm	Hardness	as $CaCO_3$	156	20	0
	Sulfate	as SO_4	5	30	540
	Chloride	as Cl	2	2	36
	P Alkalinity	as $CaCO_3$	0	34	680
	M Alkalinity	as $CaCO_3$	148	62	755
	Sulfate-Carbonate Ratio	as Na_2SO_4/Na_2CO_3			1.0
	Cycles of concentration (feedwater)				18
	Cycles of concentration (raw water)				18
	Per cent blowdown (boiler)				5.55
	Per cent blowdown (system)				5.55

System II, Fig. 2, illustrates the steam and water balance following application of recirculation to the same system. It can be noted that the total blowdown of the boiler has been increased to 10 per cent of the boiler feedwater, but the total blowdown of the system to waste has been reduced from 5.55 to 0.925 per cent.

Table II shows the analyses of the raw water, boiler feedwater and boiler water following application of recirculation. It will be noted that the boiler water concentrations are identical with those pertaining previous to recirculation with the exception of an increase in the chloride content of the boiler water from 36 to 216 ppm. Concentrations of the boiler feedwater with respect to sulfate, chloride and alkalinity have been increased considerably, however, due to the boiler water recirculated to the softener.

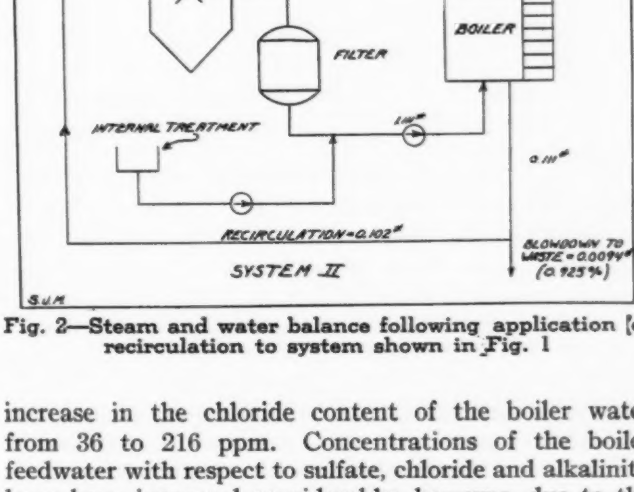

Fig. 2—Steam and water balance following application of recirculation to system shown in Fig. 1

It will be noted further that the boiler is operating under ten cycles of concentration compared to the feed-

water and 108 cycles of concentration compared to the raw water. Also, while the system blowdown is 0.925 per cent, the actual boiler blowdown is 10 per cent. The savings in fuel and water resulting through a reduction in blowdown of the system are shown below. The

TABLE II

			Raw	Feedwater	Boiler
Ppm	Hardness	as $CaCO_3$	156	10	0
	Sulfate	as SO_4	5	54	540
	Chloride	as Cl	2	22	216
	P Alkalinity	as $CaCO_3$	0	45	680
	M Alkalinity	as $CaCO_3$	148	86	755
	Sulfate-Carbonate Ratio	as Na_2SO_4/Na_2CO_3			1.0
	Cycles of concentration (feedwater)				10
	Cycles of concentration (raw water)				108
	Per cent blowdown (boiler)				10
	Per cent blowdown (system)				0.925

saving in chemical treatment due to the reduced quantity of raw water will be discussed later.

Basis—Daily evaporation = 2,000,000 lb steam
Boiler pressure = 145 lb per sq in. gage
Raw water temperature = 50 F
No exhaust steam available for heater.

In System I (without recirculation) 1 lb steam requires	1.0587 lb raw water
In System II (with recirculation) 1 lb steam required	1.009 lb raw water
Saving in raw water equals	0.0497 lb raw water

per pound of steam or 99,400 lb of raw water per day

Any raw water entering the system must be finally heated to boiler temperature. Even though this might be accomplished in steps by first being heated in the feedwater heater and finally in the boiler, this heat must be supplied from the system.

Heat of liquid at 160 lb absolute pressure	= 336 Btu per lb
Heat of liquid at 50 F	= 18 Btu per lb
Heat required from system	= 318 Btu per lb

Therefore, saving in heat due to reduction in raw water will be:

$$99{,}400 \text{ lb} \times 318 \text{ Btu per lb} = 31{,}609{,}200 \text{ Btu per day}$$

With coal of 14,500 Btu per lb and an efficiency of 75 per cent, we utilize 10,875 Btu per lb of coal. A saving of 2910 lb of coal is obtained equivalent, with coal at $5.00 per ton fired, to a daily saving of $7.28.

With a water cost of $0.10 per thousand gallons, reduction in raw water consumption is equivalent to an additional daily saving of $1.19.

Of course, most systems utilize exhaust steam for the feedwater heating. However, as long as there is some high-pressure steam throttled for use in the heater which can be replaced by the recirculated boiler water, the above fuel saving can be expected. On the other hand, if the heat in the recirculated boiler water merely replaces exhaust steam for which there is no other use, then the foregoing heat saving is not realized. In fact,

TABLE III

	Precipitable Solids in Feedwater as $CaCO_3$, Ppm	Cycles of Feedwater Concentration	Precipitated Solids in Boiler Water as $CaCO_3$, Ppm	Precipitated Solids in Boiler Water as $Ca_3(PO_4)_2$, Ppm
Without recirculation	20	18	360	372
With recirculation	10	10	100	103

an actual loss may result if the blowdown of the boiler is increased and an excess of exhaust steam makes it impossible to recover the heat of the recirculated water. In such a case it would be possible to install a heat exchanger on the feedwater between the feed pump and the boiler. The capital cost of such equipment would, of course, have to be balanced against the heat to be recovered.

Suspended Solids

With blowdown recirculation the suspended solids content of the boiler water can be considerably reduced. The suspended solids contained in the boiler water returned to the softener are naturally removed by settling in the sedimentation tank and by filtration. Since the boiler operates under a reduced number of cycles of concentration, suspended solids build up in the boiler water to a lesser extent. Inasmuch as the hardness of the boiler feedwater is reduced by the greater excess of alkalinity that can be maintained in the softener, there are less solids present in the boiler feedwater that must be precipitated internally in the boiler.

One disadvantage of this process is the increased load that is placed on the sedimentation tank and the filters. If the sedimentation tank and filters are being operated at their maximum capacity without recirculation, the increase in volume of water handled with recirculation may result in overloading of the sedimentation tank and of the filter and thus possibly result in the disadvantages of this process overweighing its advantages. It is also conceivable that if the recirculated boiler water is not introduced at the proper point that the normal sedimentation in the softener will be disrupted, decreasing its normal efficiency. The previous example can be used to illustrate the reduction obtained in the suspended solids content of the boiler water. As can be noted from Table I the hardness of the boiler feedwater without recirculation was 20 ppm, expressed as calcium carbonate. With recirculation this hardness was reduced to 10 ppm. Table III illustrates the precipitable solids in the feedwater both with and without recirculation. With proper treatment of the boiler water these solids will be entirely precipitated within the boiler.

The precipitated or suspended solids content of the boiler water will, therefore, be 360 ppm without recirculation and only 100 ppm with recirculation, expressed as calcium carbonate. If the hardness of the boiler water were precipitated totally in the form of tri-calcium phosphate through use of any phosphate such as disodium or monosodium phosphate, the precipitated or suspended solids content of the boiler water would be reduced from 372 ppm without recirculation to 103 ppm with recirculation, expressed as tri-calcium phosphate. Of course, in these calculations, it has been assumed that suspended solids will be removed from the boiler in the same ratio as will dissolved solids and that there will be no settling of suspended solids to any one point of the boiler from which they would not be removed by the continuous blowdown.

Another manner of expressing these results is that with a daily steam production of two million pounds the quantity of incrusting salts actually entering the boiler daily amounts to 42 lb, expressed as calcium carbonate, without recirculation of boiler water. With recirculation of boiler water the incrusting salts actually entering the boiler are reduced to 22 lb daily, expressed as calcium carbonate.

This reduction in the suspended solids content of the boiler water is frequently quite important both in the prevention of scale and in reduction of tendencies for carryover of solids with the steam. Reduction of sus-

pended solids by recirculation to less than one-third their previous value, as in this example, can be expected to lessen the tendency for such solids to accumulate on heating surfaces or to result in excessive amounts of sludge found on boiler openings. Since certain types of suspended precipitates exert a definite tendency for foam stabilization and consequent carryover, any reduction in concentration of these precipitates will naturally tend toward the production of a purer steam.

Sulfate-Carbonate Ratio

Since the alkalinity of the boiler water is removed in the precipitation of hardness in the softener and no such removal of the sulfate and chloride takes place, under concentration in the boiler the ratio of sulfate and chloride to alkalinity naturally increases. This is

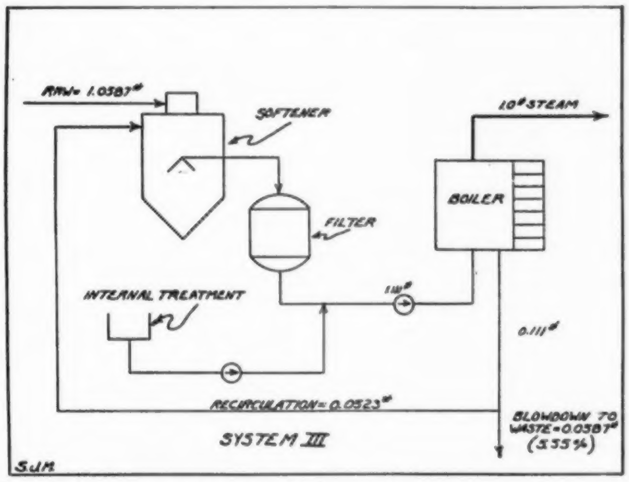

Fig. 3—Steam and water balance for system effecting a reduction in boiler water alkalinity

particularly advantageous where sodium sulfate is being used to maintain the A.S.M.E. recommended sulfate-carbonate ratios. If the sulfate-carbonate ratio is already within the prescribed limits without the necessity of adding any sodium sulfate, or sulfate in any other form, no advantage can be secured from this standpoint by recirculation of the boiler water. Again using the same example, reference to Table I will show that in order to establish a sulfate-carbonate ratio of 1.0 in the boiler water it was necessary to increase the sulfate content of the boiler feedwater to 30 ppm as SO_4. The sulfate content of the raw water was only 5 ppm necessitating the addition of 25 ppm sulfate as SO_4 to the boiler feedwater. Using anhydrous sodium sulfate this required the use of 37 ppm or 37 lb anhydrous sodium sulfate per million pounds of boiler feedwater. With a daily feedwater, under the conditions as illustrated by System I, of 2,117,500 lb, this was equivalent to the use of 78 lb anhydrous sodium sulfate daily.

In the case of the example taken the chloride content of the raw water was quite low and consequently the cycles of concentration of the boiler water could be increased considerably without unduly increasing the chloride content of the boiler water. It was possible, therefore, to adjust the recirculation in this case so that concentration of the natural sulfate in the raw water produced the sulfate content of the boiler water necessary to establish a sulfate-carbonate ratio of 1. Under the conditions illustrated by System II and Table II it was not necessary to add any sodium sulfate to the boiler feedwater in order to establish the desired sulfate-carbonate ratio in the boiler water. Concentration of the 5 ppm sulfate present in the raw water, under 108 cycles of concentration, resulted in the required concentration of 540 ppm sulfate as SO_4 in the boiler water. The use of the 78 lb anhydrous sodium sulfate daily was, therefore, eliminated. Figuring this material at a cost of 2¢ per lb, a daily saving of $1.56 resulted.

Boiler Water Alkalinity

The alkalinity of the boiler water can be reduced by recirculation inasmuch as the alkalinity contained in the blowdown water recirculated to the softener is reduced in precipitating hardness in the softener. When such a system is so arranged that a reduction in the boiler water alkalinity is effected, it is not possible to secure as great a reduction in the rate of blowdown as if boiler water alkalinity remained the same. However, it may be desired, as in many instances, to reduce boiler water alkalinities in order to minimize their effect in causing entrainment of solids with the steam. Complete facilities in the way of heat recovery on the continuous blowdown may be available so that even if blowdown could be reduced considerably through recirculation, no material advantage would be secured. Even if there is no heat recovery on the continuous blowdown system there may be an excess of exhaust steam available in the plant. Recirculation of boiler water blowdown to the softener would normally eliminate the need for a portion of this exhaust steam, but if no other means were available for utilizing the heat contained in the exhaust steam and it would otherwise simply be wasted to the atmosphere, reduction in blowdown secured by recirculation would again be to no advantage.

In System II and Table II the advantages secured by way of blowdown reduction were shown. If the same initial plant conditions as illustrated by Table I and System I are again considered and plant operation makes a decrease in boiler water alkalinity desirable in preference to reduction in blowdown, recirculation may be so arranged as to permit such a reduction in boiler water alkalinity. System III, Fig. 3, illustrates the steam and water balance that would pertain with such a condition. The actual blowdown from the boiler is increased while the blowdown to waste remains the same, the difference being recirculated to the softener.

TABLE IV

			Raw	Feedwater	Boiler
Ppm	Hardness	as $CaCO_3$	156	20	0
	Sulfate	as SO_4	5	30	300
	Chloride	as Cl	2	3.6	36
	P Alkalinity	as $CaCO_3$	0	34	378
	M Alkalinity	as $CaCO_3$	148	62	420
	Sulfate-Carbonate Ratio	as Na_2SO_4/Na_2CO_3			1.0
	Cycles of concentration (feedwater)				10
	Cycles of concentration (raw water)				18
	Per cent blowdown (boiler)				10
	Per cent blowdown (system)				5.55

Table IV shows the analyses that would result with such a system. It should be noted that boiler water alkalinity has been decreased from a total of 755 ppm, expressed as calcium carbonate, to a total of only 420 ppm, expressed as calcium carbonate, a decrease of 31 per cent. It is still necessary to add sodium sulfate to the boiler feedwater to maintain the desired sulfate-

carbonate ratio although the quantity of sodium sulfate required has been reduced from 37 to 31 ppm. This is equivalent to a reduction of 13 lb daily, or an almost negligible savings of 26¢ daily. Recirculation to reduce boiler water alkalinity is principally to advantage where high boiler water alkalinities are causing carryover of solids with the steam and where a reduction in alkalinity and suspended solids content of the boiler water will minimize this tendency for carryover.

Internal Treatment

Where recirculation has been applied so as to result in a higher alkalinity maintained on the softener effluent, there is naturally a reduction in the hardness content of the softened water. Consequently, the amount of internal treatment necessary for the precipitation of the hardness in the boiler feedwater is reduced, although not in direct proportion to the reduction in hardness on the softener effluent. In some cases the application of recirculation will result in no change in the alkalinity maintained in the softened water, as the quantity of lime and soda ash in use will simply be reduced to hold the original softened water balance. This may be the case where the hardness on the softener effluent was originally as low as can be expected from the lime-soda process and, therefore, higher alkalinity will not appreciably lower it further. In such an instance, there will be no material change in the hardness of the softened water and no reduction in the quantity of internal treatment. In fact, there will be some increase in internal treatment as the quantity of feedwater will increase and its hardness will be the same as before recirculation.

Referring to the conditions represented by Table I and Table II, it can be seen that here recirculation resulted in a decrease of feedwater hardness from 20 to 10 ppm, expressed as calcium carbonate. If, for purposes of calculation, it is assumed that the entire hardness present in the boiler feedwater will be precipitated within the boiler in the form of tri-calcium phosphate, 20 ppm anhydrous disodium phosphate will be necessary under the conditions as represented by Table I, without recirculation. Furthermore, if it is desired to feed sufficient disodium phosphate to maintain a soluble phosphate content of the boiler water of 50 ppm, under 18 cycles of concentration, an additional 4.2 ppm disodium phosphate will be required. The total quantity of treatment necessary to precipitate the entire hardness of the boiler feedwater in the form of tri-calcium phosphate and to maintain a residual of 50 ppm excess phosphate in the boiler water is, therefore, 24.2 ppm anhydrous disodium phosphate.

The conditions represented by Table II show the application of recirculation to this particular set of conditions. With a reduced hardness of 10 ppm in the boiler feedwater, the quantity of anhydrous disodium phosphate necessary to precipitate this totally as tricalcium phosphate is approximately 10 ppm. Maintenance of the desired excess soluble phosphate as 50 ppm PO_4 requires the use of 7.5 ppm disodium phosphate, under 10 cycles of concentration. The total quantity of internal treatment necessary for the precipitation of the entire hardness of the boiler feedwater as tri-calcium phosphate and the maintenance of 50 ppm excess phosphate in the boiler water is, therefore, 17.5 ppm anhydrous disodium phosphate. The total amount of disodium phosphate required with recirculation is 38.9 lb daily compared with 51.2 lb without recirculation for a daily evaporation of two million pounds steam. This represents a reduction in phosphate of 24 per cent although the hardness of the boiler feedwater was reduced 50 per cent by means of recirculation. Under the latter condition, however, the boiler operates under a reduced number of cycles of concentration compared to the boiler feedwater which requires a greater quantity of phosphate for the maintenance of a given excess of phosphate in the boiler.

Although an excess of phosphate may be present in the boiler water recirculated to the softener, this phosphate is not present in the softener effluent. Due to the greater insolubility of tri-calcium phosphate there is a preferential reaction of the phosphate contained in the recirculated boiler water with the hardness of the incoming raw water. Of course, the quantity of hardness precipitated in the phosphate form in the softener will slightly reduce the quantity of lime and soda ash necessary but the phosphate contained in the recirculated boiler blowdown is removed in the softener and is not available for further concentration in the boiler.

Under certain circumstances the quantity of internal treatment required may actually be increased with the application of recirculation. Table IV illustrates the conditions existing when recirculation is applied for the purpose of reducing boiler water alkalinity, with no reduction in the quantity of blowdown. The hardness of the boiler feedwater is not reduced but remains at 20 ppm, requiring 20 ppm anhydrous disodium phosphate for its full precipitation as tri-calcium phosphate. However, the boiler is operating under only 10 cycles of concentration compared with the boiler feedwater and, consequently, in order to establish the desired excess phosphate as 50 ppm PO_4, 7.5 ppm disodium phosphate are required. The total quantity of internal treatment necessary is, therefore, 27.5 ppm anhydrous disodium phosphate compared to the 24.2 ppm necessary without recirculation. System I shows 1,058,700 lb of feedwater per one million pounds of steam to be treated with 24.2 ppm disodium phosphate. This is equivalent to 51.2 lb phosphate daily at a daily steam production of two million pounds. System III shows 1,111,000 lb of feedwater per one million pounds of steam to be treated with 27.5 ppm phosphate. This is equivalent to 61.1 lb daily, an increase of almost 20 per cent. It can be seen, therefore, that reduction in internal treatment does not necessarily accompany the use of recirculation but, dependent upon the chemical balance maintained in the system, it may actually be increased.

As previously mentioned, when the blowdown of the system to waste is reduced, concentration of the natural sulfate of the raw water will effect a decrease in the quantity of sodium sulfate necessary for the establishment of the required sulfate-carbonate ratio. Where sodium sulfate is being used as internal treatment for the maintenance of the sulfate-carbonate ratio, recirculation can reduce or eliminate this portion of internal treatment cost. As has been noted from the previous examples, however, this advantage can only be gained to any material extent where it has been possible to reduce the system blowdown by the recirculation of boiler water.

With certain systems of applying the recirculated

boiler water to the softener, it is claimed that deaeration is improved. Under these circumstances it can be seen any sodium sulfite used for removal of residual dissolved oxygen would be decreased due to increased removal of oxygen in the softener. Internal treatment costs for chemical deaeration would thereby be decreased.

Seeding

Return of the boiler water to the softener naturally introduces the suspended solids contained in the boiler water. The introduction of these suspended precipitates from the boiler water affords a focal point for the crystallization from solution of the calcium carbonate and magnesium hydroxide precipitated in the softener. This seeding action of the suspended precipitates assists in hastening the chemical precipitation and the rapid sedimentation of the calcium carbonate and magnesium hydroxide. While individual study of each installation is required it is possible that this action can be used so as to eliminate partially, if not completely, the necessity for any coagulant applied to the softener.

Silica

The scouring action of the calcium and magnesium precipitated in a hot-process lime-and-soda softener has been credited with the reduction in silica that is effected under certain circumstances in such units. This is reduction in silica most probably in the form of SiO_2, in a practically colloidal condition. Higher concentrations of silica introduced into the softener by the concentrated boiler water might also be expected to result in an increase in the relative efficiency of silica removal. However, with silica present in the boiler water in the form of sodium silicate it is quite possible that in this form it will pass through the softener unaffected. The removal of silica by precipitation in the softener is affected by the magnesium content of the raw water, hence no definite rules or generalities are possible except over a rather broad range. Where no removal of soluble sodium silicate introduced from the boiler water is effected in the softener, silica may be expected to concentrate in the boiler water in proportion to the increase in chloride. Of course, there would be no increase in silica in System III as the blowdown of this system has not been reduced and boiler water chlorides remain the same as before recirculation.

Control of Chemical Feed

Where the balances maintained on the softened water with recirculation are those corresponding to overtreatment with lime and soda ash, or in other words, when higher softener alkalinities are maintained than without recirculation, the control of the feed of lime and soda ash is made less sensitive and thus results in easier control. It can readily be seen that if the alkalinity of the softener effluent is maintained at 86 ppm, under conditions as illustrated by Table II, a 10 per cent deficiency in the quantity of lime occasioned either by an increase in the hardness of the raw water or by insufficient charging of the chemical tank, will not affect the softener balance to as great a degree as in the case of the feedwater in Table I where the normal alkalinity maintained was only 62 ppm.

It can also be seen that such decrease in the sensitivity of chemical control is not necessarily always the result of recirculation. Table IV illustrating a different application of recirculation shows a total alkalinity of the feedwater as only 62 ppm. In this case, as in the case without recirculation, deficiencies in chemical feed will be readily apparent. In fact, greater difficulty in maintaining a consistent balance on the softener effluent will result, particularly with large load variation, inasmuch as the quantity of recirculated boiler water will not vary with load variation as will the feed of lime and soda ash, proportioned to raw water flow. The particular application to which recirculation is placed governs whether or not control of chemical feeding is made less sensitive.

Feedwater Pumping

Recirculation of boiler water to a softener inevitably increases the quantity of boiler feedwater that must be handled by the boiler feed pump. Normally, this increase in feedwater pumping cost is overshadowed by the advantages gained by recirculation. Such cost of increased feedwater pumping, of course, increases with boiler pressure. With the conditions represented by Systems I and II, with and without recirculation, there was an increase in the quantity of boiler feedwater amounting to 4.9 per cent.

External Treatment

Reduction in the quantity of lime and soda ash used for the precipitation of the hardness contained in the raw water is, of course, effected by the using up of any residual phosphate content of the boiler water returned to the softener. In addition, the recirculated boiler water contains considerable excess concentrations of sodium carbonate and sodium hydroxide. The sodium carbonate contained in the recirculated boiler water will replace a portion of the soda ash used in the oftener. The sodium hydroxide in the boiler water returned to the softener will substitute for lime in the precipitation of the magnesium salts and in the precipitation of calcium bicarbonate, thereby directly decreasing the quantity of lime that must be used in the softener. Typical reactions illustrating these precipitations are shown below. It should be particularly noticed that in the reactions between both calcium and magnesium bicarbonates and the sodium hydroxide returned to the softener, additional sodium carbonate is produced as a result of this reaction. This sodium carbonate, as well as that contained in the recirculated boiler water, will act directly in the reduction of the soda ash fed to the softener.

$Ca(HCO_3)_2$	+	$2NaOH$	=	$CaCO_3$	+	Na_2CO_3	+	$2H_2O$
Calcium Bicarbonate	+	Sodium Hydroxide	=	Calcium Carbonate	+	Sodium Carbonate	+	Water
$CaSO_4$	+	Na_2CO_3	=	$CaCO_3$	+	Na_2SO_4		
Calcium Sulfate	+	Sodium Carbonate	=	Calcium Carbonate	+	Sodium Sulfate		
$Mg(HCO_3)_2$	+	$4NaOH$	=	$Mg(OH)_2$	+	$2Na_2CO_3$	+	$2H_2O$
Magnesium Bicarbonate	+	Sodium Hydroxide	=	Magnesium Hydroxide	+	Sodium Carbonate	+	Water
$MgSO_4$	+	$2NaOH$	=	$Mg(OH)_2$	+	Na_2SO_4		
Magnesium Sulfate	+	Sodium Hydroxide	=	Magnesium Hydroxide	+	Sodium Sulfate		

An important point also to be considered in relation to reduction in external treatment is the smaller quantity of raw water to be treated, as in System II. In comparing this sytem with System I it is evident that raw water makeup has been reduced 4.7 per cent. Re-

duction in lime and soda ash will be at least 4.7 per cent, in addition to the quantity replaced by the alkalinity of the recirculated boiler water.

The reduction that is possible in the amount of lime and soda ash can be directly calculated by knowing the boiler water analysis and the steam and water balance, such as is illustrated by Systems I, II and III. It is also necessary to determine the calcium and magnesium content of the raw water, as well as the remainder of a normal mineral analysis, in order that the exact savings in lime and soda ash for any particular set of conditions may be calculated.

Dependent upon these many factors, the reduction in the quantity of lime and soda ash can be calculated. It can be stated, as a general rule, that with recirculation of boiler water to the softener there is always a savings in the quantity of chemicals fed to the softener. In some cases this reduction may be insignificant while in other cases recirculation can be economically justified on this basis, even if no other advantage is secured through its use.

Effect of Condensate

Throughout, for the sake of simplicity, we have neglected the effect of return condensate. Using 100 per cent raw water makeup, recirculation of 10 per cent of the feedwater will result in return to the softener of approximately (not exactly) 10 lb of boiler water for each 100 lb of raw water. If 50 per cent return condensate is received and we still recirculate 10 per cent of the feedwater, we will return approximately (not exactly) 10 lb of boiler water for each 50 lb of raw water. Therefore, it can be seen that more can be accomplished by the same percentage recirculation if condensate is received or less recirculation is required to produce the same effect.

Of course, there is less need of recirculation with large quantities of condensate since the desired boiler water concentrations can be maintained without excess blowdown. When the blowdown is low, such as with a high percentage of returns, a small increase in blowdown will reduce concentrations considerably.

As an example, an increase in blowdown of 1 per cent (from 1 to 2 per cent) will reduce cycles of boiler water concentration from 100 cycles to 50 cycles or a 50 per cent reduction in concentration. An increase in blowdown of 1 per cent (from 4 to 5 per cent) will decrease cycles of boiler water concentration from 25 to 20 cycles, or a 20 per cent reduction in concentration. Therefore, where the rate of blowdown is low a small increase may accomplish the desired reduction in concentration without undue heat loss, thereby reducing the need of recirculation.

Method of Installation

Where a continuous blowdown is already installed, it is relatively simple to lead the blowdown lines from each boiler to a common header with a discharge through a single line to the softener. Control of blowdown from individual boilers and discharge of boiler water to the softener can be regulated by conventional flow-control valves. In the Neckar process recirculated boiler water is discharged upward by means of nozzles in the downflow section of the sedimentation tank. The boiler

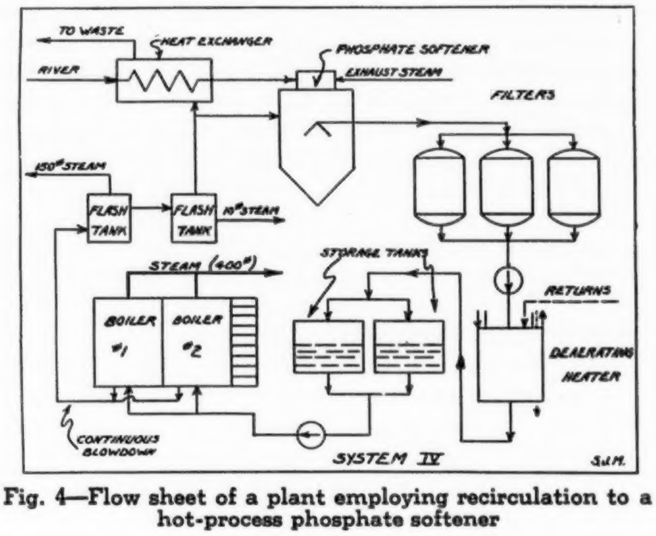

Fig. 4—Flow sheet of a plant employing recirculation to a hot-process phosphate softener

water, in other cases, is discharged below the water level in the softener at such a point as to assist in the thorough mixing of the lime and soda ash with the raw water. The continuous blow from the boilers may pass to a flash tank and in some cases through a heat exchanger before return to the softener.

External Phosphate Softening

Essentially, the same advantages and disadvantages apply to recirculation of boiler water to a phosphate softener as pertain with use of a lime-soda softener. A greater saving in external treatment cost can usually be effected with a phosphate softener, however, as the phosphate fed to the softener is more costly than lime and soda ash. In addition, the excess phosphate returned with the boiler water is not lost, as with a lime-soda softener, but it is free to concentrate and maintain the desired excess of phosphate in the boiler water.

The phosphate concentrations maintained in the softened water are increased by recirculation which results in more complete precipitation in the softener. Control is also improved as these higher phosphate concentrations are more readily determined.

TABLE V

		Raw	Softener Effluent	Boiler No. 1	Condensed Steam
Turbidity	as SiO_2	Present	None	Trace	2.0
Suspended Matter		Present	None	Trace	Trace
Carbonate Hardness	as $CaCO_3$	36	3		
Non-carbonate Hardness	as $CaCO_3$	3	0		
Total Hardness	as $CaCO_3$	39	3	0	0
Sulfate	as SO_4	20	72	536	0.3*
Chloride	as Cl	4.5	10.5	102	0.11*
Iron		Trace	None	None	None
Free Carbon Dioxide		15.0			
P Alkalinity	as $CaCO_3$	0	4	200	0
M Alkalinity	as $CaCO_3$	36	60	384	10
Phosphate	as PO_4		5.0	30	
Silica	as SiO_2			78	0.0
Calcium (gravimetric)	as $CaCO_3$		2.6		
Magnesium (gravimetric)	as $CaCO_3$		1.0		
Dissolved Solids				1802	
Suspended Solids				28	
Total Solids				1830	3.0
Ammonia as N					1.0
pH Value		6.7	8.5	11.5	6.1
Sulfate-Carbonate Ratio as	Na_2SO_4/-Na_2CO_3			2.0	

* Betz-Hellige Method

Fig. 4 (System IV) illustrates the flow sheet of a plant employing recirculation to a hot-process phosphate softener. Table V illustrates the analyses of a typical set of samples obtained from this system.

Testing Alloy Steels for Oxidation at High Steam Temperatures

By A. A. POTTER
Dean of Engineering, Purdue University

LARGE quantities of hydrogen are produced commercially by passing steam through a bed of porous iron ore, which is maintained at temperatures between 1000 F and 1500 F. During a ten-minute period about one-third of the steam passing through the bed is converted into hydrogen. As a result of the reaction the iron ore is converted into magnetic iron oxide.

Most of the high-pressure steam generating stations are now designed to operate on steam between 900 F and 930 F. In order to generate high temperature steam economically, it is necessary to have relatively high rates of heat transfer through the superheater tubes. This means that the inside surface of the metal tube must be at a higher temperature than that of the steam within the tube. The superheating elements may therefore be operated at temperatures which approach those used for the production of hydrogen from steam. It is therefore desirable to expand our present knowledge of the extent to which high-temperature steam reacts with steels in order to determine the most suitable materials for service under such high-temperature conditions.

Purdue University has been engaged for several years in an investigation which has for its objective the determination of the extent of oxidation by high-temperature steam of the various steels that are available for service at the temperatures which are being used at present or may be used in the future in modern steam generating stations. A progress report was presented before the A.S.M.E. and published in the October 1938 *Transactions* (Vol. 60, No. 7) of that Society. The present test program includes the measurement of the rate of oxidation of more than twenty different alloy steels when in contact with steam at temperatures between 1000 F and 1200 F.

It has been found that the rate of oxidation is independent of the steam pressure up to at least 1600 lb per sq in. but increases rapidly with temperatures above 1000 F. It is probable that some alloy steels may develop a dense, thin, tightly adherent layer of oxidation products which will protect the underlying metal from excessive attack by steam in much the same way that paint will protect the wood in our houses from the destructive action of the weather. If alloy steels can be found which develop such a protective coating, are reasonable in price and have certain other necessary physical properties, then higher steam temperatures will be possible in modern power plants and the thermal efficiency of such plants will be improved considerably.

During the past year a series of corrosion tests of 100, 200, 500 and 1000 hours' duration, respectively, were carried out on three specimens of each of ten different steels at 1100 F. The results showed considerable variation between presumably duplicate samples. Some variation in results is to be expected because of the nature of alloy steels, but the extent of this variation between duplicate samples was greater than the differences between some of the different alloy steels.

In order to check the effect of surface finish and the reproducibility of results, thirty-nine specimens of $^1/_2$-in. round bar stock of SAE 1020 analysis were exposed to steam at 1100 F for 500 hours. The specimens were given six different surface finishes and annealing treatments. Results indicated close agreement between specimens subjected to any one of the various types of finish with a maximum variation of 28 per cent between different surface finishes. It was, accordingly, decided to subject all specimens to annealing and sandblasting and to use $^1/_2$-in. round bar stock for the specimens. The apparatus as now built is capable of being operated with two sections in parallel and with 184 specimens all maintained at a temperature of 1100 F $\pm$ 10 deg F.

At present, tests of 200, 500, 1000 and 2000 hours' duration are being conducted on ten different steels prepared as indicated in the preceding paragraph. One section of the apparatus is being operated continuously for 2000 hours while the 200, 500 and 1000 hour tests are being run in series in the other section of the equipment. These tests will be completed during the fall. It is hoped that they may be correlated with The Detroit Edison Company tests of 4000, 8000 and 16,000 hours' duration in order to determine the effect of time and the resistance of the corrosion products to further attack.

Future plans include a series of tests at several different temperatures and also tests with the specimens subject to stress. Up to date, no tests have been made on stressed specimens.

International Conference on Flames and Furnaces Planned

Under the auspices of the Institute of Fuel and The British Coal Utilization Research Association, an International Conference on Flames and Furnaces is planned for September 17 to 20, 1940, at the Royal Institution in London.

Progress in the scientific study of flame by the methods of chemical kinetics and spectroscopy is opening up new fields that offer large engineering and industrial possibilities. One purpose of the Conference is to bring these new developments to the attention of engineers with a view to accelerating their practical application. The program will be concerned with the free combustion of gases, liquids and solids in air and sessions will be devoted to topics relating to: (a) slow combustion and ignition phenomena; (b) flame and flame propagation, including the effect of radiation; (c) combustion in polyphase systems; (d) heat transfer; (e) the furnace; (f) action of flame on materials; and (g) fuel beds and burners.

It is proposed to organize the Conference on somewhat novel lines in that the authors of papers will be invited to collaborate in covering the whole ground of flame and furnace research with the minimum of duplication and overlap. Selected authors throughout the world are being asked to contribute papers on specified problems and early in 1940 the Editorial Committee will undertake the task of coordinating the various papers into a homogeneous review of the subject. Papers will be preprinted and available prior to the Conference and individual papers will not be read at the sessions, which will be devoted to oral discussions.

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DUST COLLECTION TESTS

at New Power Plant of the Industrial Rayon Corp.

By C. B. McBRIDE, Vice Pres.,
Prat-Daniel Corporation

A series of fourteen seven-hour tests on this installation of multicyclone dust collectors serving three 80,000-lb per hr steam generating units showed an actual average efficiency of 88.4 per cent, which, corrected for draft loss and average fineness of the dust, brought the figure up to 95.03 per cent when based upon specified conditions.

IN the selection of the location for the new $11,500,000 rayon plant of the Industrial Rayon Corporation[1] consideration was given to a vicinity free from air contaminated by surrounding industrial plants, which is an essential factor in the manufacture of high-grade rayon yarn, and a locality at Painesville, O., twenty miles from Cleveland on the south shore of Lake Erie, was chosen.

By the same token it was desirable that the power plant itself emit as little dust from the pulverized-fuel-fired boilers as was commercially possible, and extensive investigation was made of all methods and apparatus commonly used on the market as dust collectors for power plants.

The Thermix Controlled Multicyclone units offered the possibility of an overall collection of pulverized fuel dust of approximately 90 per cent and had the particular advantage of allowing to escape only that dust which was extremely small in size and which would travel great distances before reaching the earth, far beyond any possibility of contaminating the products on the five hundred acre plant. This particular feature narrowed the choice to the use of mechanical collectors of various types which inherently possess this feature, although differing in degrees of overall collection possible by the various systems offered.

The boiler plant includes three Type VU, two-drum bent-tube boilers furnished by Combustion Engineering Company, Inc., for normal operation at 80,000 lb per hr (90,000 lb maximum) at 700 lb pressure and 780 F total steam temperature. Each is served by a CE-Raymond bowl mill handling bituminous coal of the following characteristics:

	Per Cent
Fixed carbon	48.3
Volatile	35
Moisture	5
Ash	11.7
Sulphur	3
Btu value, as fired	12,300

Gases from the three boilers discharge into a radial brick stack by the induced draft fans and it was not considered necessary that this stack be more than 100 ft high because of the extreme fineness of the dust that it was expected would be discharged after the dust collectors. Assuming that the gas carried an additional 25 ft vertically upward before it assumed a horizontal course, Stokes law indicates that 11 micron particles in a five-mile wind carry 6.9 miles before reaching the ground, and particles as large as 44 microns or 325 mesh would carry something over 2000 ft.

It was desired, therefore, to test the apparatus with the greatest degree of accuracy, to determine its effectiveness in keeping the atmosphere as pure as possible around the plant and in the vicinity of Painesville itself.

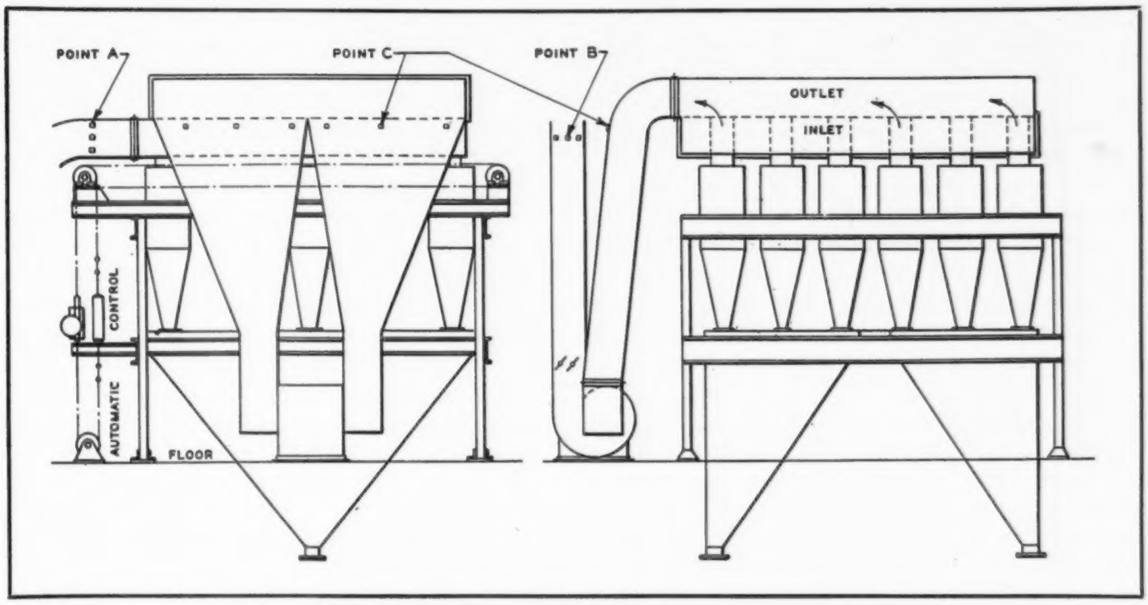
The installation of dust collectors consists of thirty Design 2 Thermix Controlled Multicyclones for each boiler, or a total of ninety units in all. Each cyclone is 2 ft in diameter and approximately 7 ft high. The upper portion consists of cast iron, and the lower portion of steel plate. In the inlet arm of each cyclone is a vertical damper. The dampers along each row of cyclones are interconnected by means of pre-stretched cable which rotate around a drum on the end of each row. This series of drums is connected to a common shaft and are revolved by means of a No. 91 Cash controller.

This controller is activated by means of a diaphragm connected with static pipes in the inlet and outlet ducts so that the draft loss across the cyclones will be maintained constant at varying loads. Thus, when the load decreases, the draft controller closes all of the dampers to a slight extent, thus retaining high inlet velocity of the gas when entering the cyclone, which compensates for the lower centrifugal force encountered because of the lower gas velocity with a lighter gas load.

Preliminary Investigation for Tests

As shown in the attached sketch, there was a fairly straight horizontal run of duct from the air heater to the dust collector, and a straight vertical run at the fan inlet. It was hoped, therefore, that the difficult question of

[1] For description of plant see COMBUSTION, December 1938.



Sketch showing points at which measurements were taken

obtaining fair samples at inlet and outlet would be easily answered in this installation.

Approximately twenty sampling points were installed about half-way between the dust collector and the plate-type air heater. It was not possible, however, to obtain accurate and check results due to the fact that a constant load for a twenty-four hour period was not practical at the time of testing, and a considerable settling of dust occurred in the horizontal run of duct, about 4 in. deep.

The tests were then repeated with the duct blown entirely clean previous to testing, but the concentration according to tests then appeared to be too low, due to the fact that the dust had a tendency to settle out in the duct both before and after tests. A lighting system was installed so that the condition during operation along the bottom of the duct could be observed, and it was noticed that considerable dust was sliding along the flue in spite of the fact that the elbow at the heater outlet should have centrifugally thrown much of the dust to the upper portion of the duct.

At the outlet, the duct was sampled in a number of locations, but there were great variations in velocities according to pitot tube readings, principally due to the fact that the fan outlet dampers were partially closed since the boiler was then operating at 60,000 lb load instead of 90,000 lb.

Thus it was determined that at these locations neither inlet nor outlet samples could be considered accurate within a reasonable area.

The location of the outlet sampling station was then changed to the flue connecting the dust collector and the fan, and at this point uniform velocities were observed, although at first it was feared that dust stratification would result due to the bend. The impossibility of obtaining accurate samples at the inlet, however, required the actual weighing of the dust collected over the period of tests.

Various Checks Employed

In order to obtain exact knowledge as to the loading in the gas it was necessary to measure the total gas volume passing through the collector and at the same time to check this by analysis of the amount of coal fired, per cent of ash in the coal and combustible in the ash. The amount of ash remaining in the boiler was unusually small, and it was, therefore, also possible to check by calculation the amount of total fly ash passing to the collector in the gas.

A final method of test, therefore, consisted of determining gas volume by means of pitot tubes and determining the outlet dust loading at point *C*, taken in uniform areas across the duct and equaling this against the weight of

TABLE 1—RESULTS OF TEST

Test Number	Lb of Steam per Hr	Cu Ft per Hr at 70 F	W. G. Resist.	Total Caught in Lb	Hours Run	Grains per Cu Ft Caught	Outlet Temp., F	Outlet Sample, Ounces	Outlet Sample, Cu Ft 70 F	Grains per Cu Ft Lost	Total Grains per Cu Ft	Lb of Dust per Hr Caught	Efficiency Per Cent
152	50,000	937M	1.55	2,629	7.27	2.70	330	2.88	3,292	0.384	3.084	363	87.6
153	53,000	995M	1.25	2,223	6.88	2.28	330	2.63	3,288	0.350	2.630	324	86.8
154	51,000	956M	1.25	3,220	6.54	3.62	330	2.88	3,322	0.379	3.999	493	90.3
155	57,000	1070M	1.25	1,972	6.57	1.96	340	1.88	2,633	0.314	2.274	300	86.3
156	51,000	956M	1.25	2,345	6.42	2.68	340	3.25	3,434	0.415	3.095	366	86.7
157	52,000	975M	1.25	3,309	7.25	3.28	340	2.75	3,436	0.350	3.630	457	90.3
158	42,000	787M	1.25	2,181	6.84	2.84	340	2.88	3,434	0.367	3.207	320	88.5
159	56,000	1050M	1.25	4,048	7.20	3.74	340	2.25	3,434	0.287	4.027	562	93.0
160	61,000	1143M	2.00	3,641	7.92	2.82	340	3.00	3,420	0.384	3.204	461	88.0
161	60,000	1125M	2.00	4,832	8.44	3.55	344	3.50	2,590	0.592	4.142	572	85.8
162	66,000	1234M	1.50	5,949	7.42	4.55	344	4.625	3,663	0.55	5.10	800	89.3
163	64,000	1200M	1.50	6,457	8.28	4.55	340	5.75	4,233	0.594	5.144	780	88.5
164	66,000	1234M	1.50	4,906	7.03	3.96	338	4.5	3,860	0.51	4.47	699	88.8
165	66,200	1130M	1.50	5,316	6.43	5.10	355	6.375	3,984	0.70	5.80	825	88.0
Averages			1.45										88.4

164 Burned 7,230 lb coal per hr.
165 Burned 7,700 lb coal per hr.
All grain loadings at 70 F.
CFH calculations 152 to 164 inclusive at 84 per cent efficiency and 15 per cent CO_2.
CFH calculations 165 at 84 per cent efficiency and 16.5 per cent CO_2.

dust collected. The results of the tests were as shown in Table 1. It is to be noted that these tests were run on fourteen consecutive days and the method of procedure used was checked not only by the plant engineers, but also by a group of engineers from various utilities during the final two days of the test.

It will be noted that the average length of test was seven hours of continuous operation. The amount of dust discharged at the higher ratings expressed in the latter four tests ranged between 4906 and 5949 lb, and the total grains per cubic foot (figured at 70 F) at these points varied between 4.47 and 5.8 grains.

Results of Screen Analyses

Screen analyses were made of the dust collected, which was carefully prepared from quartered samples obtained from each barrel of dust taken from the hopper on the tests indicated. These are given in Table 2.

TABLE 2—SCREEN ANALYSES OF DUST

Test	155	157	159	161	162	163	165	Average
On 200	11.6	13.0	8.3	11.0	12.7	13.1	13.5	11.9
On 325	9.7	9.5	7.2	10.4	9.6	9.9	10.6	9.5
Through 325	78.7	77.5	84.5	78.6	77.7	77.0	75.9	78.5

Due to the impossibility of obtaining fair samples at the inlet it was not possible to determine the analysis of the entering dust except by calculation. Observation indicated that there were no particles of material coarser than 325 mesh or 44 microns which were escaping the dust collector. Therefore, the fineness of the entering dust could be actually determined from the efficiency calculation by dividing the percentage of dust through 325 mesh in the collected sample by the efficiency of collection. This is shown in Table 3.

TABLE 3—ANALYSIS OF DUST IN FLUE GAS

Test No.	Percentage Dust Through 325 Mesh
155	91.0
157	86.0
159	91.0
161	91.8
162	87.0
163	87.8
165	86.1
Average	88.6

These calculations, of course, may be slightly affected due to breakage of particles during collection, but nevertheless the dust is unusually fine, due to not only the excellent pulverization but also to the relatively low rating of the boiler, resulting in a lower velocity of gas and the carry-over to the dust collector of a finer dust than would be the case with a higher velocity at higher ratings.

This brings to mind the fact that the system of control contemplated for the installation made it possible to obtain as good collection as this at lower ratings, whereas if the control had not been used the collection would have perceptibly decreased since the centrifugal force would have dropped as the square of the gas volume. In other words, whatever the centrifugal force, because of gas velocity through the cyclones at 90,000 lb of steam per hour, this would have resulted in $\frac{60^2}{90^2} \times 1 = 44.4$ per cent, as much as at the maximum rating.

The lower velocity and centrifugal force remain in the cyclone body but because of the close proximity of the control dampers to the outside edge of the inlet arm of each cyclone, the distance which a dust particle must travel to reach the metallic sides of the cyclone where it is precipitated is materially reduced, and the inlet velocity is actually increased at lower ratings over what it would have been at higher ratings.

In the anticipated performance of a dust collector a definite efficiency figure, based upon previous observations, must be given and this figure is dependent upon temperature, draft loss and the fineness of dust.

The temperature of the flue gas affects overall collection due to the fact that the viscosity of gas increases as the temperature increases in spite of the lower density at the higher temperature. Reference is made to the "Handbook of Chemistry and Physics," which gives the result of these determinations at various temperatures, showing, for example, that gas at 392 F is 44 per cent more viscous than at 0 F. It is evident that the more viscous the gas, the more difficult it is to penetrate, and with dust particles, therefore, the collection will decrease with higher temperatures.

In this instance the question of temperature was approximately that anticipated so that this fact did not enter into collection calculations. The anticipated collection was based upon dust having 60 per cent through 325 mesh and with a draft loss of 1.9 in. on the collector. The collection allows for 1 per cent drop in efficiency for each 5 per cent increase in dust through 325 mesh, and for 0.2 per cent drop in efficiency for each 0.10-in. drop in resistance. It is to be observed, however, that this must be within reasonable limits.

The average efficiency for these tests was 88.4 per cent. The average draft loss was 1.45 in. and the average fineness of dust charge, as calculated above, 88.67 per cent. The collection will then calculate,

$$88.4 + \frac{(1.90 - 1.45).2}{0.10} + \frac{(88.67 - 60)}{5} \times 1 = 95.03 \text{ per cent}$$

which is approximately $2^1/_2$ per cent higher than the expected collection on this installation.

A point of interest is the fact that a comprehensive test, such as described above, requires not only skilful engineers, experienced in the particular technique of testing for dust quantities in gas, but a corps of assistants, so that the total is approximately five or six men and an extended preliminary series of observations. The preliminary observations in this instance consumed two weeks.

It is not often appreciated that difficult conditions may present themselves and that a considerable allowance must be set aside if it is desired to test a dust collection installation with any degree of satisfaction.

Welding Scholarships—Two $250 scholarships in welding engineering will be awarded at Ohio State University annually, starting this fall, through the generosity of an alumnus. According to James R. Stitt, assistant professor of welding, juniors and seniors in the welding engineering curriculum are eligible. Normally one scholarship will go to each of these classes, although it is provided that where one class is lacking in an eligible candidate both men may be selected from the other. Last year Ohio State inaugurated a four-year course in welding engineering, perhaps the first college in the country to undertake such a program.

Resistance to Flow Through a Tube Bank

These results of measurements on boiler and superheater tubes, made in a wind tunnel at the Delft College of Engineering, show the influence of tube arrangement and spacing on the resistance to flow as offered by the tube bank. An expression for this resistance is developed, from which curves are plotted. The application of these data to the actual boiler where heat transfer takes place is discussed.

GASES flowing over a tube bank create a resistance whose magnitude depends on several factors, including the number of rows, the arrangement of tubes, their spacing with reference to their diameter, the presence of slag or ash accumulations, and whether heat transfer is taking place.

In view of certain investigations, the results of which have been published in this country, a series of tests conducted at the laboratory of the Delft College of Engineering (Holland) and reported by Prof. Dipl.-Ing. A. J. Ter Linden in *Die Wärme* of May 13, 1939, are of particular interest.

These investigations were made on boiler tubes in a wind tunnel in which the air and tubes were at the same temperature; hence no heat transfer took place. While this fact exerted a favorable influence on the exactness of the readings taken, the results can be applied to an actual boiler only if the gas properties are evaluated at the proper temperatures.

Test Apparatus

Fig. 1 shows the arrangement of the test apparatus. The width of the tunnel being approximately $3^1/_2$ ft permitted the use of full-size boiler and superheater tubes. These tubes had been in service for some years in a sectional-header boiler and, although thoroughly brushed, were somewhat rougher than new tubes. Therefore, their condition was comparable to that of tubes in an actual boiler that had been cleaned. However, contrary to expectations, it was found that the roughness of the surface had little effect on the total draft loss. More important in an actual boiler is the reduction in gas passage between tubes, due to ash or slag deposits.

During the tests the following readings were taken:

1. Volume of air passing through the tube bank.
2. Temperature, pressure and humidity of this air.
3. Difference in static pressure between points A and B.

In order to determine the resistance through the tube bank alone, the resistance between points A and B was found with the tube bank removed and this was deducted from the previously measured resistance between the same points with the tube bank in place, both measurements employing the same air volume. Thus the resistance to flow determined in this manner comprises the total resistance of the tube bank, including the entrance and exit losses. It was found that the resistance of the wind tunnel itself had an appreciable effect on the total draft loss with a tube bank of less than three rows of tubes, but for a greater number of rows this can be neglected. Because of irregularities in flow it was somewhat difficult to obtain accurate and consistent readings of static pressure immediately behind the tube bank, hence the readings at B were taken at a considerable distance beyond the bank.

Results of Measurements

The total resistance of the tube bank, Δp, in kilograms per square meter, at a gas velocity w, measured in meters per second at the most restricted area between two adjacent tubes in a plane, can be expressed as follows:

$$\Delta p = \zeta \frac{w^2 \gamma}{2g} \qquad (1)$$

where g is standard acceleration due to gravity (9.81 m per sec^2) and γ the density of the air in kilograms per cubic meter. ζ is a demensionless friction factor determined by the Reynolds Number, Re, and by the arrangement of the tubes in the bank. This arrangement is defined in terms of the dimensions indicated in Fig. 2, where d is the diameter of the tube, s_1 the center-line transverse spacing, s_2 the depth spacing (center to center), b the center-line distance between staggered

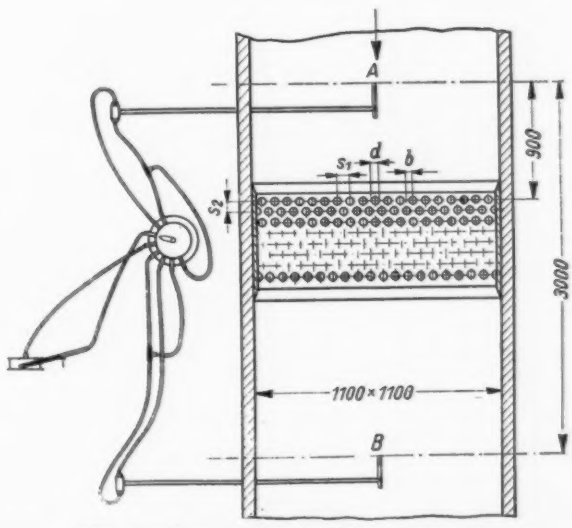


Fig. 1—Arrangement of test apparatus

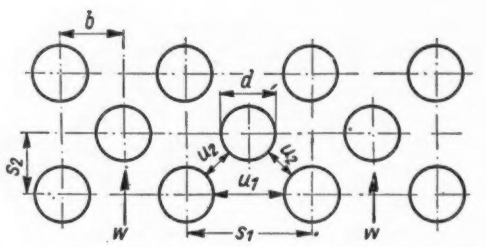


Fig. 2—Section through a tube bank with spacings indicated

tubes, u_1 is horizontal clearance between adjacent tubes and u_2 the diagonal clearance between staggered tubes. Obviously, for tubes in line b becomes zero and for equally spaced staggered tubes b becomes $^1/_2\, s_1$.

The expression, $\zeta = \dfrac{\Delta p}{\dfrac{w^2\gamma}{2g}}$, is plotted on a logarithmic scale against the Reynolds Number, *Re*, for different arrangements in a number of diagrams of which several are here reproduced. In these n represents the number of rows. Fig. 4 applies to a bank with tubes in line, whereas all the others represent staggered tubes, with $b = {}^1/_2\, s_1$.

For a definite tube arrangement and number of rows the following relation is approximately true.

$$\zeta = c(Re)^m$$

where m and c represent constants which are functions of the relations of s_1, s_2 and d, and the number of rows.

Where the tube bank consists of one or two rows the value of ζ may become irregular and in isolated cases (see Fig. 5 where $n = 2$) the resistance offered by two rows may actually exceed that of three rows with the same tube arrangement. Where $n = 1$ the value of ζ is practically independent of *Re* and the pressure drop increases almost proportionally to the square of the gas velocity.

To illustrate the influence of the relations of s_1, s_2 and d upon the resistance of the tube bank with staggered tubes the author presents Fig. 7 in which ζ is plotted for different ratios of s_1 to d with $Re = 10{,}000$ and $s_2 =$

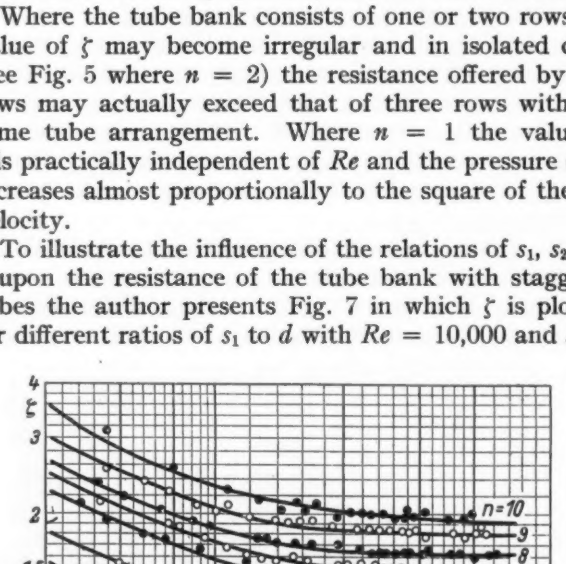


Fig. 3—Curves of ζ plotted against Reynolds Number for different numbers of rows of 4-in. tubes, where $s_1 = 1.75\, d$, $s_2 = 1.49\, d$ and $b = 0.45\, d$

TABLE I

$Re = 10000$	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$
$s_1/d = 1{,}45$	0,46	0,8	1,01	1,4	1,65	2,00
$s_1/d = 1{,}75$	0,43	0,88	1,10	1,4	1,7	2,1
$s_1/d = 1{,}94$	0,43	0,78	1,11	1,4	1,69	2 02
$s_1/d = 2{,}42$	0,33	0,68	0,97	1,25	1,53	1,95
$Re = 25000$	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$
$s_1/d = 1{,}45$	0,46	0,71	0,88	1,16	1,35	1,6
$s_1/d = 1{,}75$	0,43	0,85	0,97	1,20	1,46	1,71
$s_1/d = 1{,}94$	0,43	0,83	1,03	1,21	1,45	1,7
$s_1/d = 2{,}42$	0,34	0,69	0,9	1,11	1,32	1,59
$Re = 50000$	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$
$s_1/d = 1{,}45$	0,46	0,64	0,8	1,02	1,17	1,35
$s_1/d = 1{,}75$	0,43	0,85	0,88	1,05	1,28	1,48
$s_1/d = 1{,}94$	0,43	0,85	0,95	1,07	1,28	1,48
$s_1/d = 2{,}42$	0,35	0,7	0,84	1,02	1,19	1,37

0.87 s_1. The curves are quite flat, which indicates that draft losses are only slightly influenced by the ratio of s_1 to d. The differences are so small that for practical purposes the value of ζ in equation (1) can be taken as

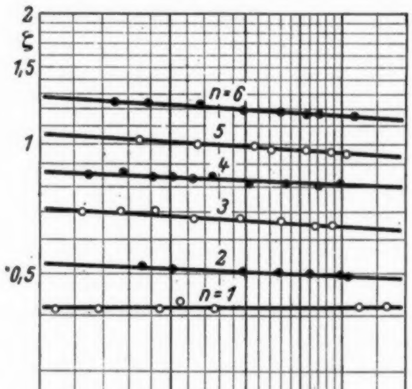


Fig. 4—Curves of ζ plotted against Reynolds Number for 1¼-in. tubes in line where $s_1 = 1.69\, d$, $s_2 = 1.69\, d$ and $b = 0$

TABLE II

$Re = 10000$	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$
$s_2/d = 0{,}97$	0,43	1,04	1,66	1,96	2,4	2,88
$s_2/d = 1{,}09$	0,43	1,04	1,18	1,38	1,67	2,15
$s_2/d = 1{,}24$	0,43	0,97	1,12	1,34	1,71	2,08
$s_2/d = 1{,}35$	0,43	0,91	1,09	1,36	1,73	2,15
$s_2/d = 1{,}57$	0,43	0,81	1,05	1,34	1,72	2,03
$s_2/d = 1{,}67$	0,43	0,78	1,12	1,40	1,69	2,02
$s_2/d = 1{,}93$	0,43	0,79	1,08	1,40	1,77	2,15
$s_2/d = 2{,}24$	0,43	0,81	1,17	1,54	1,85	2,17
$Re = 25000$	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$
$s_2/d = 0{,}97$	0,43	1,21	1,38	1,65	1,98	2,35
$s_2/d = 1{,}09$	0,43	1,02	0,99	1,17	1,46	1,73
$s_2/d = 1{,}24$	0,43	0,93	0,96	1,12	1,41	1,62
$s_2/d = 1{,}35$	0,43	0,92	0,96	1,19	1,43	1,19
$s_2/d = 1{,}57$	0,43	0,84	0,97	1,20	1,48	1,68
$s_2/d = 1{,}67$	0,43	0,83	1,03	1,21	1,45	1,70
$s_2/d = 1{,}93$	0,43	0,81	1,02	1,25	1,52	1,75
$s_2/d = 2{,}24$	0,43	0,84	1,07	1,32	1,57	1,8
$Re = 50000$	$n = 1$	$n = 2$	$n = 3$	$n = 4$	$n = 5$	$n = 6$
$s_2/d = 0{,}97$	0,43	1,24	1,22	1,44	1,7	2,04
$s_2/d = 1{,}09$	0,43	1,00	0,87	1,04	1,32	1,46
$s_2/d = 1{,}24$	0,43	0,92	0,87	0,98	1,22	1,35
$s_2/d = 1{,}35$	0,43	0,93	0,87	1,09	1,25	1,91
$s_2/d = 1{,}57$	0,43	0,85	0,92	1,10	1,31	1,46
$s_2/d = 1{,}67$	0,43	0,85	0,95	1,07	1,28	1,48
$s_2/d = 1{,}93$	0,43	0,84	0,97	1,14	1,35	1,50
$s_2/d = 2{,}24$	0,43	0,87	1,00	1,17	1,38	1,59

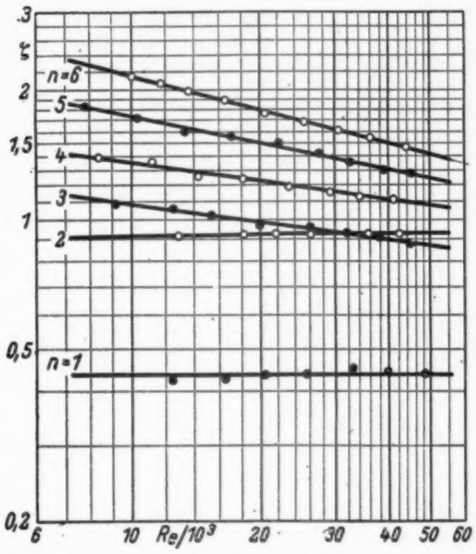


Fig. 5—Curves of ζ plotted against Reynolds Number for 1¼-in. staggered tubes where $s_1 = 1.94\ d$, $s_2 = 1.35\ d$ and $b = \frac{1}{2}\ s_1$

a constant and the pressure loss can be expressed in terms of gas velocity w between the tubes.

Further examination of Fig. 7 discloses that ζ decreases for a narrower passage between tubes as well as for a wider passage than that indicated by $s_1/d = 1.5$ to 2. The flat form of such curves will also be apparent if other values of Re be used from Table I.

To determine the influence of the depth spacing on resistance to flow, a fixed ratio of $s_1/d = 1.94$ was assumed and the ratio s_2/d altered. The results are tabulated in Table II.

Also, values of ζ have been plotted against s_2/d in Fig. 8 for a Reynolds Number of 10,000. These curves indicate that a definite value of s_2/d exists for the least draft loss through a given tube bank. This value is not far from the ratio s_2/d which is represented by $u_1 = 2u_2$ (see Fig. 2); that is, when the free area between the tubes of the first row is equal to the sum of the diagonal free areas between two tubes of one row and one tube of the next. The minimum value for ζ falls between $s_2 = 1.3\ d$ and $s_2 = 1.5\ d$.

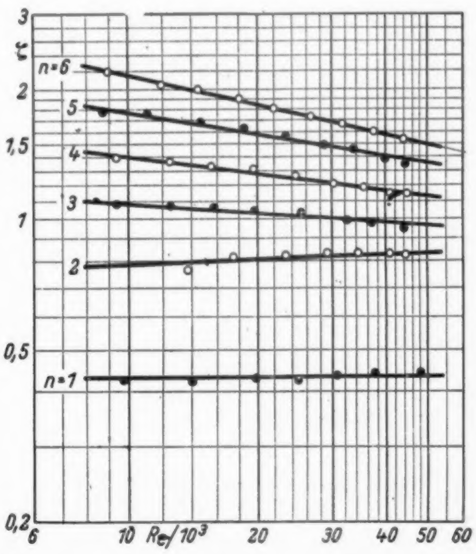


Fig. 6—Curves of ζ plotted against Reynolds Number for 1¼-in. staggered tubes where $s_1 = 1.94\ d$, $s_2 = 1.93\ d$ and $b = \frac{1}{2}\ s_1$

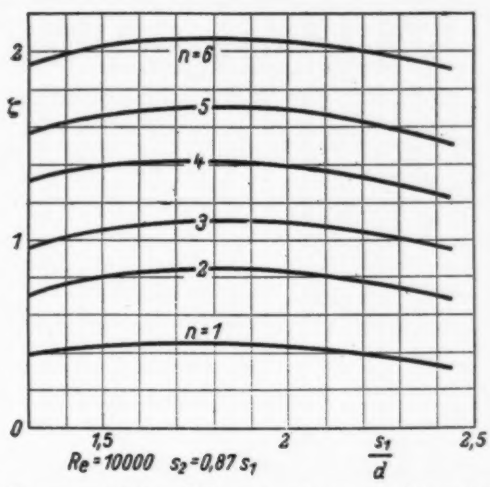


Fig. 7—Curves of ζ for different values of s/d and for $s_2 = 0.87\ s_1$ with $Re = 10{,}000$

It is interesting to note that with increase of u_2 an increase, instead of a decrease, of flow resistance takes place. Therefore, the author recommends keeping the depth spacing below 1.5 d, whereby $u_2 = 0.78\ u$, for the obvious reason of keeping the depth of tube bank at a minimum.

Resistance of Tube Banks in which Heat Transfer Takes Place

As previously pointed out, the foregoing applies directly only to tube banks without heat transfer and in which the viscosity, temperature and density of the flowing gases remain the same throughout. In practice, however, large temperature differences exist between the flowing gases and the tubes. The difficulty in applying these values to the actual case appears to lie in the selection of proper values for w, γ, etc. While the exact values can be determined only from additional tests under heat transfer conditions, approximate results may be had by taking average values for w, γ and the temperature. For the evaluation of the gas

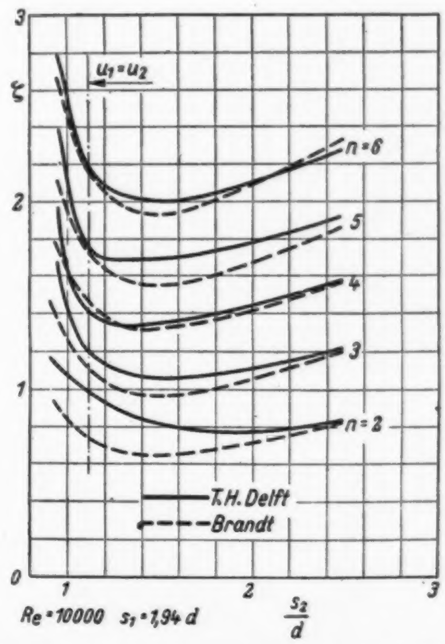


Fig. 8—Curves of ζ for different values of s_2/d, and $s_1 = 1.94\ d$, with $Re = 10{,}000$

viscosity the film temperature can be used and for all practical purposes this can be taken as the metal temperature at the outside surface of the tubes. Hot gases flowing over tubes having relatively low temperatures, as in water-tube boilers, will have a film viscosity much lower than that at mean gas temperature. Therefore, the resistance to flow will be lower than that in a tube bank in which the tube temperature equals the mean gas temperature. The cooler gases of the film zone may be likened to a lubricating medium between the tubes and the hot gases.

However, where the tube temperature is higher than the average gas temperature, as in the case of air preheaters, the viscosity in the film zone will also be higher than the mean viscosity, and the resistance of the tube bank will be higher than that based on equal tube and gas temperatures, other conditions being equal.

Editor's Note: It should be noted by those interested in the conclusions drawn from Figs. 7 and 8 that these figures are not directly comparable. In plotting Fig. 7 the depth spacing s_2 was not held constant as was the transverse spacing in Fig. 8. For every change in s_1 for Fig. 7 there was a corresponding change in s_2, as indicated by the relationship $s_2 = 0.87\ s_1$ or, in other words, the geometric relationship between s_1 and s_2 was constant for Fig. 7 but variable for Fig. 8.

American practice differs from European practice in the use of linear gas velocity in heat transfer and draft loss calculations. Because the temperature and therefore velocity changes continually as heat transfer takes place, most American engineers make use of mass velocity G in their formulas, where $G = w\gamma$ (author's nomenclature) and is therefore in terms of weight per unit of time per unit of flow area. Using G in the Reynolds Number changes its expression to $Re = dG/\mu$ where Re is dimensionless and d, G and μ are in consistent units.

For convenience in comparing these data with the results of American investigators on this subject the author's equation may be put in the following form:

$$\Delta p = \frac{\zeta}{n} \times \frac{1}{43.3 \times 10^8} \times \frac{G^2}{\rho}$$

where Δp = flow resistance, inches, w.g. per restriction
G = mass velocity, lb per hr per sq ft
ρ = gas density, lb per cu ft
ζ = author's dimensionless friction factor as plotted in his Figs. 3 to 6, inclusive
n = number of tube rows or restrictions

Selection and Care of Lubricants*

By J. K. RUMMEL, Chemist
The Shanghai Power Company

The limitations of standard specifications and accelerated tests as an index to the useful life of an oil are reviewed in the light of service conditions, and the influence of oiling systems, containing steel and copper that serve as catalysts for oxidation, is discussed, as well as the effect of gland seal leakage.

SINCE lubricating oils and greases made from petroleum and other materials are the products of chemical and engineering effort, it is natural that the power company chemist should take a serious interest in their selection and their care while in use. In this connection the data of their changes and performance during service, as distinguished from general opinions not based on definite data, are of considerable importance. In the collection of these data, close cooperation between all interested parties is very essential.

Consider first the difficult problem of selection and evaluation of lubricants. It is a well-known fact that petroleum is a mixture of many molecular compounds which differ somewhat as to general type, lubricating value and stability. They also vary with the source of the crude oil. The selection and refining of these oils is entirely in the hands of the oil companies and, as a rule, the purchaser has no guidance other than his faith in the integrity of the oil company's manufacturing procedure for certain brands of lubricants. Since the analysis of petroleum oil for molecular composition is a most difficult problem, which is taking up the time of many research laboratories, it is obvious that such chemical tests as are made must be of a limited nature only. Unfortunately, the tests now given in standard specifications are not sufficiently significant to determine lubricating or lasting qualities, and they do not give enough information on the changes that take place in the oil during service, so that the end of useful life can be accurately stated. They do, however, tell us whether the oil has the same general characteristics as an oil that has given relatively good service, and deductions are made from this.

Further tests are being developed to show the amount of decomposition products dissolved in a used oil, and others to give a more accurate analysis of suspended matter or sludge. Considerable work has been done by way of accelerated life tests, but since the conditions are not the same, the same decomposition products are not produced or at least not in the same ratio. Thus, the stability on accelerated test may not be assurance of superior stability in service. Service tests themselves are not exact in that the peculiarities of individual machines will differ and the machines will be harder on the oil under certain conditions of operation. Therefore, a final conclusion as to the relative stability of individual lubricants requires a knowledge of the condition of the oil after considerable periods of use under all the significant conditions of service.

The relative lubricating values of the several oils are not directly determined by this method and while this is a question of fundamental importance and should be included in any comparison of quality, we can for practical purposes assume that: (1) Petroleum products as recommended by reliable manufacturers are generally good lubricants; (2) poor lubricants are likely to be found by the usual analyses or shortly after being put in service; and (3) accurate tests for comparative lubricating value are not as yet a matter that can be turned over to the power company laboratory, as this will remain a problem for the research laboratory for some time to come.

Turbine Lubrication

One of the most interesting and instructive examples of evaluating and caring for lubricants deals with the lubricating oil used for steam turbine-generators. Here we find considerable variation in oil capacity, general design, and method of handling the oil for the different turbine-generators, but the operators usually expect or hope that the oil will give a long and serviceable life in all turbines.

As might be expected, this ideal situation is not always attained and the fault does not always lie with the quality of the oil. Such things as the design of the turbine oiling system, the condition of the gland seals permitting more or less water or steam to mix with the oil, the amount of oil leakage and new makeup added, the temperature of the bearings, and the care taken in cleaning the oil and the system during operation are all important considerations.

Of course, very little can be done with the design of the oiling system, as installed by the turbine manufacturer, but it is hoped that this will be the subject of more serious study than appears to have been the case in the past. Aside from failure to avoid some obviously poor features in regard to handling the oil and to provide ample cleaning facilities, the system usually contains a great deal of iron surface which continues to rust and provide non-lubricating sludge and a catalyst for further oxidation of the oil. Copper is another element that is known to

* Excerpt from a paper on "Chemical Work and Problems in the Power Industry," presented before the Engineering Society of China.

be a catalyst for oxidation and is used in certain oxidation tests of new oil; yet we find a prevalence of copper-wire strainers through which oil is to pass. Also, we find no good system for regulating steam pressure on gland seals, thus leaving it to the operators to guess how far to open valves on high-pressure steam lines, in order to prevent an excessive amount of water being mixed with the oil. In this connection the impurities that may be in the steam should also be considered.

A long series of analyses of oil and sludge from turbines has shown that the more water taken in with the oil the greater the oxidation and organic sludge formation and the greater the generation of ferrous and non-ferrous metal sludge per running hour. The increase in total sludge from all causes, including that from outside contamination, is significant of poorer lubrication and greater wear of turbine parts and bearings, which in the final analysis is likely to be a much greater economic loss than a shorter life of the oil.

It follows that the condition of the oil during service is the criterion for the extent and frequency of its purification. If it is found to be carrying noticeable amounts of sludge and water, purification is started and continued until this condition is improved. At the same time, the source of the contamination is considered and corrected to whatever extent may be practical. Centrifuging the oil in a continuous-flow centrifuge is the common way of removing most of the water and sludge. This may be supplemented by a filter press similar to that used for transformer oil. Since centrifuging tends to mix considerable air with the oil and assists in its oxidation, large air-sealed centrifuges and intermittent operation are preferred to small open centrifuges with more continuous operation.

Avoidance of Contamination

The life of a turbine oil is seriously affected by the admixture of partly decomposed oil or oil sludge, and in starting a new batch of oil in a turbine every care should be taken to clean all parts of the oiling system thoroughly. Also, during operation only new oil should be added as makeup. For the same reason it does not, as a rule, pay to add large amounts of new oil to old oil batches in the hope of making a gain in average life.

In selecting turbine oils on the basis of their performance data, it is found that this does not promise to be as simple a matter as might be expected. For example, one particular brand of oil was found to give excellent results as to acidity increase, tendency to emulsify and production of sludge through most of its useful life. The time came, however, when there was a definite breaking point, the acidity increased rapidly and this was usually accompanied by considerable formation of sludge, thus ending its usefulness. Another oil, for which much less data are available, shows indications of a gradual rise in acidity and tendency to emulsify and make sludge but gives a longer useful life than the first oil mentioned. It is suspected that the final breaking point in any oil marks a time when a considerable part of the oil has become oxidized, the products thus formed speeding up the formation of acids and heavier or unstable molecules which form sludge. In the case of a sudden break, as in the first oil mentioned, it is assumed that the molecular composition is less stable than that of the second oil and an oxidation and acid-forming inhibitor has been added for its preservation.[1] However, this inhibitor is finally consumed by the reactions that take place and a general breakdown of the oil occurs. In the oils not containing an inhibitor the breaking point may not be very definite and may cover several thousand hours as compared with less than one thousand hours in the inhibited oil before the breaking point is reached.

In cases of this kind, it is necessary to look a little further and see which of the oils is the most generally reliable in all turbines (some being definitely harder on the oil than others) and which appears to permit the greatest wear of turbine parts due to impurities that develop during service or other factors. In any event it requires a long period of trial and considerable accumulated data to find the real differences in values between good turbine oils.

Other Lubricants

The methods adopted for handling turbine oil, and the lessons learned from experience with it, may be applied to a limited extent to other lubricating oils and machine lubrication. However, each application should merit some special study both in selecting the best oil for the machine and the care it should be given.

Selection of greases and their application may also be profitably studied by the chemist and engineer. In a well balanced lubrication program each part to be lubricated and the economy of selecting and using various lubricants are all given such individual attention as may be necessary to insure smooth operation with a minimum of bearing failures and excess wear.

[1] The case cited had to do with one oil only (in which the inhibitor has not been identified as such) and not inhibited oils in general. Also the service life for this oil was not as short in all turbines in the station mentioned as is indicated. It should be noted further that this same oil is reported to be giving much longer service in many other turbines in other stations.

After making a further investigation since returning to this country, the author finds that some refining processes for certain crude oils may remove natural oxidation inhibitors while at the same time removing the objectionable materials present, and the only apparent alternative is to add a natural or synthetic inhibitor to the refined oil. Considerable research along this line is in progress and it is believed that this should lead to a real advance in good service characteristics and long life of many lubricating oils. In this connection there is a great deal of interest shown in perfecting laboratory life tests which should include consideration of the worst conditions expected in the steam turbine oil system. This involves the application of heat and agitation and the presence of water, air and catalysts.

The rate at which an oil finally breaks down may be of considerable importance to operation, in that it may not always be convenient to make an unscheduled stop for cleaning the turbine oil system prior to adding new oil. In this case oil breaking down at a slower final rate might be preferable. Lack of cleaning may shorten the life of this new oil batch by many thousand hours—J. K. Rummel.

Alabama Reverses Stand on Public Ownership

Despite opposition on the part of the Federal Works Administrator, the Alabama state legislature on August 15 passed a bill that will prevent the duplication of private electric systems by public undertakings. The bill requires municipalities within that state which contemplate the establishment of municipal power systems first to make a reasonable offer for the purchase of existing private power facilities, such offers to be subject to appeal to the public service commission or to the courts. This is a marked reversal of attitude from that shown in 1935 when the legislature enacted a number of bills devised to encourage public ownership of public utilities within that state.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Electrical Progress in Poland

In view of the present European situation an article by A. G. Moss in *The Electrical Times* (London) of August 3, discussing electrical progress in Poland, is pertinent. Its power resources consist of extensive coal fields in the southwest, numerous water power sites along the rivers of the Carpathian foothills and farther to the north vast fields of natural gas. Although the population is predominantly agricultural and the standard of living of the peasants relatively low, the demand for electricity has grown 40 per cent during the last six years. According to the latest available figures public utility plants supply approximately one-third of the electricity and two-thirds is privately generated. In the former, Poland has about $1^1/_2$ million kilowatts of installed capacity in plants of more than 1000 kw.

Despite the financial burden of building up and supporting a large army and setting up an industrial system during recent years, the government is engaged in building several hydroelectric developments on the River Dunajec and the River San and has plans for the early erection of two steam-electric stations using gas and coal which will cost over four million dollars in addition to three million recently appropriated.

Novel Turbine Rotor Construction

Die Wärme of March 4, 1939 describes a German-built turbine-generator of unusual construction which has lately been installed in a plant in Bucharest. It is a 15,000-kw single-cylinder condensing machine operating at 260 lb and 660 F steam temperature. The major part of the heat drop is utilized in multistage reaction blading, there being a single-velocity stage at the high-pressure end.

The construction of the spindle for the reaction blading is novel in that it is built up of a number of forged disks which are welded together, as shown in the accompanying sketch. It is claimed that this type of construction precludes any loosening of the wheels or keys at high temperatures. The construction makes for rigidity and it is believed that some saving in weight is effected. The blading is of stainless steel.

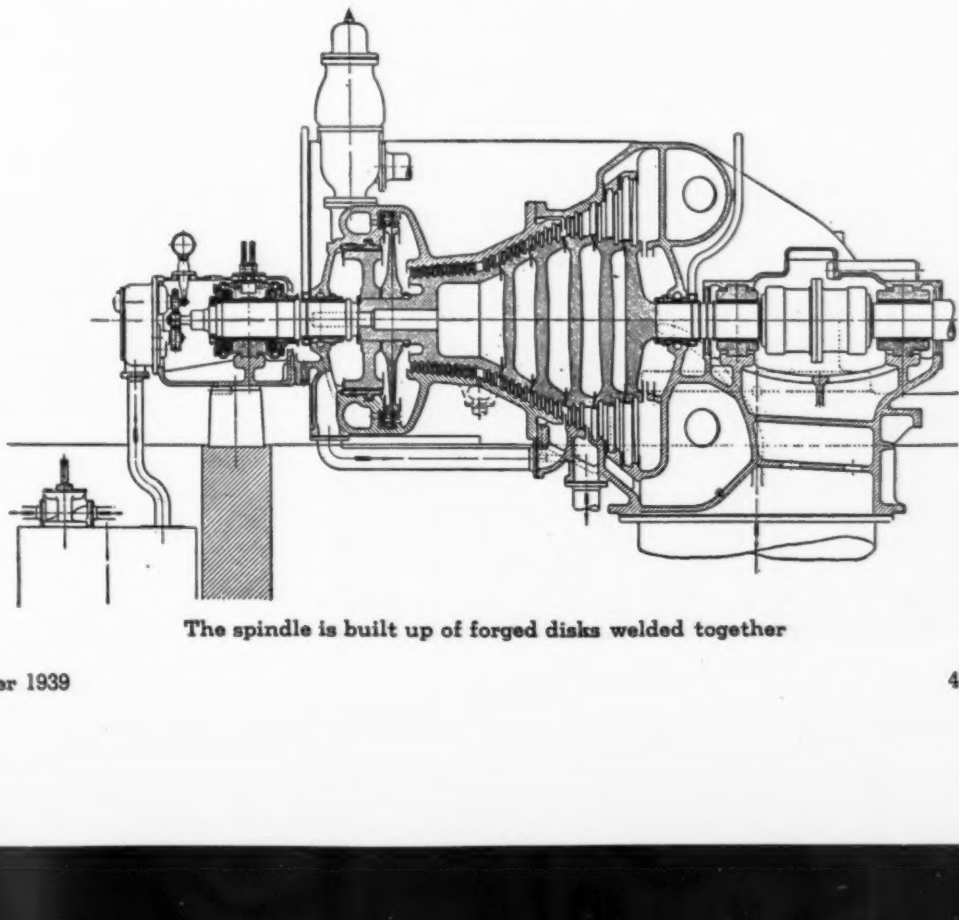
Largest Chimney in England

Engineering and Boiler House Review for August gives details of the new chimney that is to be built to serve the extension to the Hams Hall "B" power station. This will extend from the ground level instead of being carried on the building steelwork. It will be 400 ft high, 27 ft diameter at the base and 22 ft at the top and will require approximately two million bricks in addition to 400 tons of terra cotta capping. It is said to be the largest chimney in England.

Performance of British Power Stations

The Steam Engineer of August reviews the recent report of returns made to the Electricity Commissioners by generating stations in Great Britain for the year ending December 31, 1938. These indicate a continuation of the policy of closing down a number of the less efficient stations as the load is being taken over by the newer plants. During the year 21 stations were closed down and three new ones brought in. The 374 stations reporting generated over 24 billion kilowatt-hours which is 6.4 per cent more than the preceding year.

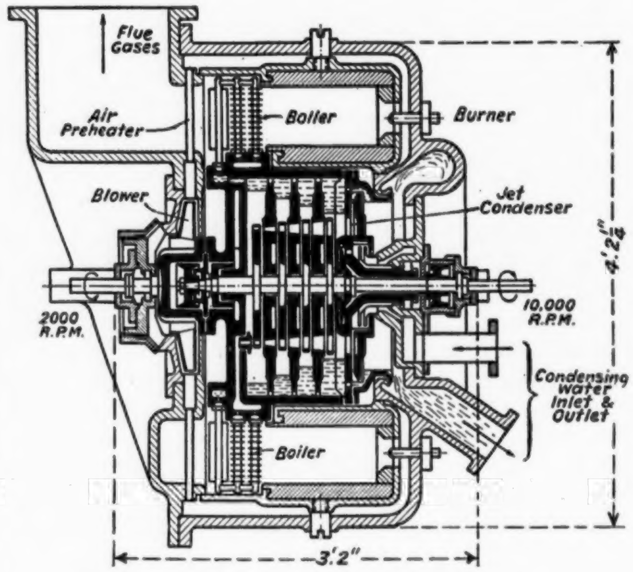
The highest thermal efficiency was attained by Dunstan "B" station of the North Eastern Electric Supply Company with 27.85 per cent, compared with 27.7 per cent for Battersea which held the best record for 1937. Excluding the 36 most efficient stations, the thermal efficiencies for the groups of smaller stations ranged from 13.5 to 20.48 per cent.



The spindle is built up of forged disks welded together

Combined Turbine and Rotary Boiler

The principle of the rotary boiler is not new, but in *Zeitschrift des Vereines deutscher Ingenieure* of April 8, 1939, Fritz Hüttner describes an experimental design in which the turbine, condenser, rotary boiler, fan and air heater are combined into a compact single unit, with considerable saving in weight. Referring to the cross-section,[1] the boiler completely surrounds the turbine,



Cross-section of turbine and rotary boiler

the gas- or oil-fired combustion chamber remaining stationary while the radial U-shaped, finned, steam-generating tubes rotate in a direction opposite to that of the turbine; this rotation being produced by the reaction of the steam leaving the nozzles. Forced draft is produced by the fan mounted on the boiler shaft, which discharges through the stationary air heater to the combustion chamber.

The steam generated in one leg of the U-tube is balanced by the water in the other leg under pressure produced by the centrifugal force of rotation, the water level depending upon the rotative speed and steam pressure. Exhaust steam is condensed by a jet arrangement, the cooling water being introduced near the turbine shaft and subjected to centrifugal action by the rotating vanes shown. In passing through the exhaust space it therefore entrains any air that is present. Moisture from condensation of the expanding steam is thrown out into troughs in the feedwater circuit. It is claimed that very high rates of heat transfer are attainable and that the permissible rotative speeds allow operation at 200 lb steam pressure or more. An evaporation of 51 lb of water per square foot of heating surface per hour is claimed.

The total weight of the unit has been figured at 2.45 lb per turbine horsepower for a 500-hp unit and less for one of larger capacity.

No commercial units have yet been built, but several small experimental machines have been constructed.

[1] Reproduced from a translation in *The Power & Works Engineer* of July 1939.

REVIEW OF NEW BOOKS

Any of the books reviewed on these pages may be secured from Combustion Publishing Company, Inc., 200 Madison Ave., New York

Arc Welding

This book contains 109 selected prize papers from the James F. Lincoln Arc Welding Foundation $200,000 Award Program. A wide variety of subjects is covered by the collection, dealing with arc welding in design, manufacture and construction in various fields. These are arranged in ten sections, namely automotive, aircraft, railroad, watercraft, structural, furniture and fixtures, commercial welding, containers, machinery and jigs and fixtures.

Printed in convenient size, 6 × 9 in., and bound in semi-flexible leather, the book sells for $1.50 in the United States and $2 elsewhere.

Treatment of Coal with Oil

By J. M. Pilcher and R. A. Sherman

Issued as *Technical Report No. VI* of Bituminous Coal Research, Inc., this publication is based on a $2^1/_2$-year program of research at Battelle Memorial Institute. It reveals that petroleum oils and blends of oil with wax and asphalt are suitable materials to allay dust, but to obtain proper treatment at minimum expense the correct oil must be used for different coals. For instance, low-volatile coals from West Virginia may be treated equally well with light or heavy oils, whereas high-volatile coals from West Virginia, Pennsylvania and Kentucky require higher viscosity oils, and coals from Indiana, Illinois and the far West are best treated with heavy, highly viscous oils or blends of oil and wax or oil and asphalt.

The report indicates how many quarts of oil must be applied per ton for the different sizes of various coals. The investigations indicated that such treatment eliminates 80 to 95 per cent of the coarse dust and 95 to 99 per cent of the floating dust, although it has no appreciable effect on the burning of coal nor on spontaneous heating of stored coal.

Lubricants and Lubrication

By James I. Clower

Based upon a combination of teaching and long practical experience in the lubrication field, the author has produced a book for purchasers and users of lubricants, as well as for those who design and operate machines that must be lubricated. The first eleven chapters deal with the fundamentals of lubricants of all types, including their production, characteristics and testing. These are followed by chapters on the lubrication of steam turbines, steam engines, air compressors, refrigerating machines and internal-combustion engines; also the proper methods to be employed in storing and handling lubricants. An appendix contains an oil-measurement table and viscosity charts.

There are 464 pages, 6 × 9 in., and 332 illustrations; price $5.

Coal Analyses

Macquown's "Proximate Coal Analyses," recently issued, contains complete authentic information on the analyses of any size coal from every shipping mine, based on data filed with the National Bituminous Coal Commission by the District Producers Boards. The figures are published in separate books for each district in handy pocket size and include complete cross-indices, showing alphabetical lists of companies and mines. Prices for the analyses for Districts 1 to 10, inclusive, are $10 per copy and for other districts, $5 per copy.

Grindability Indices

By R. E. Gilmore and J. H. H. Nicolls

This covers the results of investigations by the Fuel Research Laboratory of the Canadian Bureau of Mines as to the grindability indices of typical Canadian and other coals and the relation of grindability to friability. Coals from Alberta and British Columbia are not included. The tests reported were made by the Hardgrove-machine method but the equivalent ball-mill method index is indicated in each case. The initial, softening and fluid temperatures of the ash are also given. It is observed that pulverizer capacity is proportioned to grindability up to about 60 grindability index, but falls off at the higher grindabilities.

Piping Handbook

By J. H. Walker and Sabin Crocker

This is the third edition, the first having been brought out in 1930. Changes in power-plant practice since then, involving much higher steam temperatures and wide adoption of welding in piping fabrication, also new methods of pipe manufacture, advances in metallurgy and new standards, have necessitated thorough revision of much of the text.

Following the inclusion of much fundamental material on definitions, formulas, tables and the properties of fluids, the book takes up the metallurgy of piping materials, valves and fittings, insulation, hangers and supports, the expansion and flexibility of various piping arrangements, steam power-plant piping, building-heating piping, plumbing systems, water-supply piping, fire-protection piping and pipe for oil lines. Tables of various standards are included as well as charts and numerous illustrations.

The authors are, respectively, Superintendent of Central Heating, and Senior Engineer, Engineering Division, The Detroit Edison Company, and have had long and intimate association with piping problems from the standpoints of design, operation and committee work. The purpose of the book is to provide authoritative data for the engineer engaged in piping design. There are 897 pages; size $4^1/_2$ × 7 in.; price $6.

Results of Municipal Lighting Plants

Under this title the consulting engineering firm of Burns & McDonnell has just published its sixth edition (1939) of an electric rate book showing the operating records of earnings, output, rates, revenues, valuation and other information as to the use and cost of electricity in more than seven hundred municipally-owned plants.

The volume of 350 pages includes many interesting graphs and tables showing the increasing use of electricity and the decreasing cost of electricity, over half the plants listed having reduced their rates since the 1937 edition was brought out. It provides a convenient source of information for managers of both private and municipally-owned plants. The price is $5.

Standard Chemical and Technical Dictionary

By H. Bennett

This is a condensed compilation of 25,000 definitions for students, writers, technicians, engineers and scientists who need assistance in keeping up with the many new chemical, physical, mathematical and engineering terms. It covers industrial products, chemicals, trade names and symbols used in mathematics, chemistry and thermodynamics. A special section is devoted to the explanation and naming of organic compounds.

In view of the extent to which chemical problems now enter into the power plant field the book has an important, though limited, application to that field. It sells for $10.

Vapor Charts (Second Edition)

By F. O. Ellenwood and C. O. Mackey
Professors of Heat-Power Engineering, Cornell University

These charts give the thermodynamic properties of water, ammonia, freon and mixtures of air and water vapor, the steam values being based on the latest Keenan and Keyes Tables. By arranging the steam charts in twenty-one 7 × 10-in. sections, each on a page instead of the usual single sheet, close reading is more convenient and better protection is afforded the charts, particularly where they are used often. They are drawn on a logarithmic volume scale with specific enthalpy as ordinates and specific volume as abscissae, for a pressure range from 0.18 in. Hg up to 5500 lb per sq in., temperatures up to 1200 F and volumes from 0.05 to 3500 cu ft per lb. Constant-temperature curves have been drawn in the superheated region.

In view of the trend toward high pressures an entirely new chart, showing specific enthalpy, volume and entropy, has been drawn for water up to 6000 lb per sq in. There have also been included tables of jet velocities, squares of numbers expressed in millions by the nearest four figures and corrections to readings of the mercury column. The book should be especially useful to practicing engineers and designers having to do with problems relating to modern high-pressure steam-generating units and steam turbine calculations, as well as refrigeration and air conditioning. It has 43 pages and is priced at $2.50.

1939 Utility Chart

By R. A. Burrows

This is the sixth utility chart compiled by the author but is the first revision since that of 1936. It contains a vast amount of data concerning the interrelation and capitalization of the principal public utility holding, operating and investment companies as of June 1, 1939. The areas served by the electric and gas utility systems, as well as the Bell Telephone System, are shown on maps; and by means of diagrams are shown interrelations, voting stocks, capitalizations, gross revenues and net income, operating ratios and other financial data. Contracts for the interchange of power are indicated. The price of this 28 × 34-in. chart is $2 in black and white, or $3 in nine colors.

Steam, Air and Gas Power

By W. H. Severns and H. E. Degler

This is primarily a textbook for engineering students in which fundamentals of thermodynamics is followed by a consideration of fuels and combustion, heat cycles, steam, compressed air, etc. From the standpoint of application, chapters are included covering steam generation, feedwater treatment, various auxiliaries, steam engines, steam turbines, condensers and oil engines. Many typical problems are inserted and the appendix contains abridged steam tables from the latest published values of Keenan and Keyes, as well as other useful tables such as the student would need in working out the problems.

In preparing this third edition the authors, who are professors of mechanical engineering at the University of Illinois and the University of Texas, respectively, have revised much of the text and substituted new illustrations to bring them in line with recent progress in heat-power engineering.

The book has over 500 pages, 6 × 9 in., illustrated, and is priced at $4.

Heat Power

By E. B. Norris and Eric Therkelsen

Intended to meet the needs of an introductory course in the principles and applications of heat-power engineering, the book departs from the usual approach to the subject by first taking up internal-combustion engines, then combustion, work, heat and power, steam, and the various components of the steam plant, and finally, refrigeration. Much of the text is descriptive, although fundamental principles are fully covered and mathematics have been used only where necessary.

In preparing this second edition the authors have replaced the earlier illustrations by those representative of present practice and have included the most recent available data on the properties of gases and the specific heats of gases. The chapter on refrigeration has been added, as well as a combustion calculation chart and answers to problems.

There are 432 pages, 6 × 9 in., with 266 illustrations and numerous charts and tables. The price of the book bound in cloth is $4.

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request.

Compressors

A new line of industrial compressors and vacuum pumps in sizes of from $^{3}/_{4}$ through 5 hp is announced in an illustrated catalog, 7502-J, covering the complete line of Ingersoll-Rand Type 30 compressors. These new compressors, embodying a simplified finger valve construction, form only one part of the complete range of Type 30 compressors, which are built in sizes up to 15 hp for pressures as high as 1000 lb. They are available with or without drive, receiver-mounted or bare. The catalog contains both installation and shop views of the machines, together with complete operating and physical characteristics of each.

Draft Gages

Bulletin 9-c recently issued by Ellison Draft Gage Company describes the line of Ellison inclined draft gages, tells how to use them, how to use a pitot tube, and contains barometric tables with directions for their use.

Dust Collectors

A new type of tubular dust collector, for use where space and weight limitations prevail, is described in a folder, No. 107, issued by Prat-Daniel Corporation. The apparatus consists of a series of steel tubes, each having two slots in its upper half and directional vanes, the lower half of the tubes extending into the dust hopper through a tube sheet. The gas enters the inlet plenum chambers and passes through the slots in the tubes, rotating around a smaller central tube which extends below the slots in the outer tube and upward to a tube sheet which forms the bottom of the outlet duct. The dust is precipitated against the side of the outer tube.

Furnace Refractories

This is the title of a 12-page bulletin issued by McLeod & Henry Co., dealing with "Carbex" and steel mixture refractories for boiler and industrial furnaces. The bulletin is fully illustrated and informative.

Mechanical Draft

An attractive and informative 36-page catalog, No. 3624, on mechanical draft equipment has been issued by American Blower Corporation. Its complete line of fans is covered, performance curves of different types are compared, typical arrangements for induced draft are shown, and a discussion of mechanical draft fan selection is included.

pH Instruments

A new bulletin giving complete information regarding Bristol's pH instruments has recently been published. Description is given of the recording and controlling instruments themselves, the amplifier unit, the electrodes and lead wire. With the equipment referred to in this bulletin, hydrogen-ion concentration may be placed under the same close control as that of other process variables.

Priming Equipment

Automatic priming equipment for centrifugal pumps is described in a bulletin published by the De Laval Steam Turbine Company. In this system the water level on the suction side of the pump is automatically lifted above the eye of the impeller and held there, just as if the pump were located below the supply, the vacuum producing device being called upon thereafter only in the case of exceptional air inleakage or when the pump is not running. Ordinarily, where the main pump is not designed to run unprimed, it is shut down automatically should a break occur in the suction line. However, where the main pump is so designed that it will not be injured by running dry, as where it is to be driven by a synchronous motor with limited pull-in torque, the system may, by a slight change in the electrical and sealing connections, be arranged to prime the pump while running. The system here described employs neither floats nor a central vacuum tank, and remains operative so long as electric power is available for the main pump motor.

Vane Control

Sturtevant vane control, which consists of a series of adjustable vanes located in the inlet of a mechanical draft fan, permitting the output of the fan to be regulated to produce any desired volume of flow at the exact pressure needed to move this volume through the system, is described in a 28-page illustrated catalog recently issued by B. F. Sturtevant Company. Included is a discussion of the principle of vane control, comparison of vane control with variable-speed and damper control, characteristic curves, application diagrams, installation photographs, etc.

Water Softeners

Bulletin No. 602 issued by Elgin Softener Corporation deals with four types of zeolite water softeners, namely, the downflow, upflow, two-flow and the carbonaceous types, each of which is fully described and their respective applications discussed. Auxiliary equipment for modernizing existing softeners is included and space is devoted to Elgin aerator equipment.

Wrought Iron Products

A. M. Byers Company has lately issued a general catalog containing standard specifications, dimensions and other essential information on its line of wrought-iron products such as pipe, tubings and fittings. A section is devoted to a discussion of the characteristics of wrought iron and its fabrication.

BOOKS

1—Oil Burners

By Kalman Steiner

436 pages Price $4.50

This is an exhaustive treatise by the chief engineer of the Consumers Petroleum Company of Chicago, embracing a discussion of fundamental and advanced engineering as well as practical methods of oil burner design; also, the characteristics, specifications, combustion and handling of fuel oils. Chapters are devoted to representative domestic, commercial, industrial and power types. Auxiliary equipment such as fans, pumps, piping, strainers, heaters and controls are dealt with in detail, and considerable space is devoted to oil storage and maintenance of equipment. Practical installation data are included. The appendix contains numerous tables of use to the designer of oil-burning installations.

2—Axial Flow Fans

By Kurt Keller

140 pages 6 × 9 Price $4.00

This work is based on investigations made by the author at the laboratories of the Escher Wyss Company of Zurich and deals with the complete axial-flow fan unit, consisting of the inlet, the guide vanes, fan wheel and the diffuser. The elementary airfoil theory is employed to establish the relations between pressures, volumes and efficiencies. The mutual interference of the airfoil grid is also considered. Performance data are included on a series of axial-flow fans having 4 to 20 blades with both the guide vanes and the runner blades adjustable for angular setting. The test results show that single-stage, axial-flow fans can be calculated accurately by means of this elementary theory and that it is only in the case of fans having a large number of blades, intended for high pressures, that mutual interference in the airfoil grid becomes sufficiently large to justify modification of the theory.

The book is essentially one for designers, and Professor Marks, in adapting the text to this purpose, has omitted or abstracted some of the original material on research.

3—Elements of Steam and Gas Power Engineering

By A. A. Potter and J. P. Calderwood

374 pages 8 × 5½ Price $2.75

This is the fourth edition, the text of the 1930 edition having been largely rewritten and brought in line with developments in practice during the interim. Also, most of the illustrations dealing with equipment and its use are new.

The text is divided into three parts, the first dealing with steam power in its various aspects, the second with internal-combustion engines and the third with the application of steam and gas to motive power. Although written primarily as a textbook for engineering students, the treatment is non-technical and provides a comprehensive review of current practice. Of particular interest is the first chapter dealing with the social significance of power including pertinent statistics and the relative importance of different types of prime movers.

4—Thermodynamics

By H. A. Everett

430 pages Price $3.75

This book presents an exposition of the fundamental subject of engineering thermodynamics sufficiently comprehensive so that the student of engineering upon mastering and assimilating its contents will have a good working knowledge of this important science upon which can subsequently be built an understanding of the design and operation of power plant, refrigerating and air conditioning equipment.

In the preparation of this treatise the author has developed the subject from its fundamentals. No effort has been spared to make the text full and complete where such is necessary to properly explain the steps taken. Since the book is designed for students having a good mathematical background, mathematical analyses are given in complete detail. The entire book is profusely illustrated with figures, diagrams and graphs.

Especially is the book well developed in its earlier pages wherein the elemental material is presented. The first chapter explains the basic mechanical theory of heat. Considerable space is devoted in the second chapter to explaining the kinetic theory of gases in order that students may more easily comprehend the subsequent material. The fundamental laws of the science and the simple changes of state are discussed at length in the third chapter.

The book should prove especially valuable not only to the engineering student or instructor who wishes a thorough treatment of the subject but as well to the practicing engineer for purposes of review or reference.

5—How to Buy, Sell and Burn Coal

By T. A. Marsh

97 pages Price $1.00

This is a pocket-size booklet, with flexible cover, written in non-technical language, for the guidance of those concerned with fuel distribution, selection and utilization. The significance of different coal characteristics is explained and the fundamentals of coal burning equipment described. Of specific value to the operator is a schematic analysis of troubles and their remedies which covers over thirty pages. pages. Space is also devoted to boiler testing, smoke abatement and general combustion information.

6—Air Conditioning, Heating and Ventilating

By J. R. Dalzell and C. L. Hubbard

571 pages Price $4.00

This is a practical treatise dealing with the fundamentals of heating, ventilating and air conditioning and their application in a non-technical or "how-to-do-it" manner. Numerous typical examples are given and their solutions worked out.

The contents include: Fundamentals of Air Conditioning, Comfort Standards, Insulation, Heating Boilers, Ventilating Systems, Radiators, Direct Steam Heating, Hot-Water Heating (both natural and forced circulation), Vacuum Systems, Fans, Firing Equipment, Automatic Controls, Air Conditioning Appliances, Cooling Methods, Air-Conditioning Units and Applications.

7—Combustion, Flames and Explosion of Gases

By Bernard Lewis and Guenther von Elbe

415 pages Price $5.50

The text of this book is divided into four parts, namely: (1) chemistry and kinetics of the reactions between fuel gases and oxygen; (2) propagation of flames, in which are discussed the influence of vessel shape and gas motion, flame photography and theory of the burning velocity; (3) state of the burnt gas; and (4) problems in technical combustion processes.

Those concerned with design involving basic combustion phenomena will find the book helpful.

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Annual Fuels Meeting

Advances in the use of bituminous coal and anthracite will be discussed at the Third Annual Joint Meeting of the Fuels Division, A.S.M.E., and the Coal Division, A.I.M.E., which is to be held at the Deshler-Wallick Hotel, Columbus, Ohio, October 5 to 7.

Mining methods, engineering service, new firing equipment, slag research, testing techniques, flame photography, steel melting and the manufactured gas industry are some of the subjects relating to the central theme of coal utilization on which well-known authorities will speak. The program includes four technical sessions, the annual dinner, at which Dean A. S. Langsdorf of Washington University's engineering school will speak, and a morning of visits to manufacturing plants and industrial research laboratories. The program follows:

Thursday, October 5, 10 a.m.

SYMPOSIUM: EFFECT OF MINING METHODS ON CHARACTERISTICS OF COAL

Bituminous Deep Mining, by T. F. Downing, Jr., Philadelphia Electric Company

Bituminous Strip Mining, by W. C. McCulloch, United Electric Coal Cos.

Anthracite Deep Mining, by Prof. J. W. Buch, Pennsylvania State College

Thursday, 2 p.m.

Coordination of Fuel Engineering From the Mine to the Consumer, by T. R. Workman, West Virginia Coal and Coke Co.

A Code for Testing Coal, by R. L. Rowan, General Coal Co.

Industrial Firing of Anthracite, by William Lloyd, Combustion Engineering Company

Thursday, 7 p.m.

ANNUAL DINNER

Toastmaster, C. E. MacQuigg, Dean of Engineering, The Ohio State University

Speaker, A. S. Langsdorf, Dean of Engineering and Architecture, Washington University

Friday, October 6, 9:30 a.m.

Use of Pulverized Coal as Fuel for Open Hearth Furnaces Melting Steel for Castings, by J. P. Kittredge, National Malleable and Steel Castings Co.

Measurement of Pressures Developed During the Carbonization of Coal, by C. C. Russell, The Koppers Co.

Coal and Gas, by A. M. Beebee, Rochester Gas and Electric Co.

Friday, 2 p.m.

The Viscosity of Coal-Ash Slags, by P. Nicholls and W. T. Reid, U. S. Bureau of Mines

Notes on the Photographic Study of Furnace Combustion, by A. A. Markson and W. H. Dargan, Consolidated Edison Co., New York City

Illustrated by both black and white and colored still and motion pictures of flames and furnaces.

DISCUSSION:

Motion pictures of pulverized coal flames, Windsor Station, by Otto deLorenzi, Combustion Engineering Company, Inc.

Motion pictures of residential stoker fuel beds, by S. Konzo, Engineering Experiment Station, University of Illinois

Other pictures will be welcomed. Projectors for 16 mm motion picture film, 2 × 2-in. miniature slides and standard $3^1/_4$ × 4-in. slides will be available.

Saturday, October 7, 9 a.m.

INSPECTION TRIPS

Jeffrey Manufacturing Co.

Battelle Memorial Institute

Columbus Municipal Light Plant

Columbus and Southern Ohio Electric Co.—Big Walnut and Pickway Steam Stations

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